Lacamas Lake Restoration Program:
WY 2000 and WY 2001 Water Quality Monitoring

Clark County Public Works
Water Resources Section

Prepared for the

State of Washington Department of Ecology

and the

Lacamas Lake Restoration Program Advisory Committee

Prepared by:

Jeff Schnabel

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Acknowledgements

Thanks to the staff of Clark County Public Works, Water Resources Section, all of whom contributed to the success of this monitoring effort. Special thanks to Project Manager Robert Hutton, and to Cindy Meats, Derrick Brooks, and Jennifer Tierney for their outstanding field support despite all manner of challenges.

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1.0 INTRODUCTION

1.1 Background and Purpose

Background

Lacamas Lake and Round Lake are located in Clark County, Washington, approximately two miles north of the city of Camas. The watershed of these lakes covers approximately 43,000 acres and lake surface area is 322 acres. The lakes are an important recreational attraction and also provide water for industrial use at the Georgia Pacific paper mill in Camas.

Periodic water quality monitoring by the Southwest Washington Health District (SWHD) from 1974-1980 raised concerns about water quality problems in Lacamas Lake and its tributary streams. In 1983, the Clark County Intergovernmental Resource Center (IRC) received a Washington Department of Ecology (DOE) grant to fund a Phase I Diagnostic and Restoration Analysis. That study, the first comprehensive evaluation of water quality conditions in the watershed, concluded that the lake suffered from severe eutrophication due to high nutrient loading from the watershed. Water quality problems in the lake included dissolved oxygen depletion, poor water clarity, high levels of algae growth, nuisance blue-green algae blooms, and dense stands of aquatic macrophytes.

Subsequently, the Lacamas Lake Restoration Program (LLRP), funded in part by a DOE Centennial Clean Water Fund grant, has pursued a program of agricultural Best Management Practice (BMP) implementation, water quality monitoring, and public education in the watershed. Water quality investigations have been an integral component of LLRP activities. LLRP staff conducted an ambient water quality monitoring program in the watershed during 1991 and 1992 (Lafer, 1994).

More recently, Clark County contracted with E&S Environmental Chemistry, Inc. (E&S) to perform additional ambient monitoring and several specialized water quality investigations during 1995-1997. These monitoring activities confirmed that Lacamas Lake continued to exhibit eutrophic conditions. The Lacamas Lake Watershed Restoration Project Program Review (1998) by E&S provides an overview and summary of project activities and findings since 1984.

The LLRP contract with E&S Environmental Chemistry ended in December 1997. Since that time, LLRP staff have continued ambient water quality monitoring activities. Additional monitoring results may be found in the Lacamas Lake Restoration Program Water Quality Monitoring Report: October 1998-September 1999 Water Year (June 2000), by Clark County Public Works.

Purpose

The Lacamas Lake Restoration Program grant from the Centennial Clean Water Fund expired on December 31, 2001. This report presents selected historical data, and new data collected during water year (WY) 2000 and WY 2001 (October 1 1999 through September 30 2001). It is the final monitoring report for the grant-funded period of Lacamas Lake restoration work. Results are being used to evaluate nutrient dynamics and lake condition in order to maximize the efficiency of future lake management efforts.

1.2 Goals and Objectives

The goals of the LLRP water quality monitoring program for WY 2000 and WY 2001 were to :

1) Collect representative data describing the long-term ambient water quality status of Lacamas Lake and Lacamas Creek, and

2) Provide decision-makers with more complete information regarding the nature and effect of pollutant loading to Lacamas Creek and Lacamas Lake.

Specific objectives associated with these goals during the monitoring period were to:

1) Update the existing stream discharge rating curve for Lacamas Creek at Goodwin Road

2) Assess the effects of storm event runoff on water quality in Lacamas Creek

3) Estimate annual pollutant loads to Lacamas Lake (total phosphorus and total suspended solids)

4) Continue collecting ambient water quality data in Lacamas Lake to assess long-term trends and compare current and past conditions.

5) Better define the sources and extent of nitrate inputs to Lacamas Creek, and

6) Perform limited biomonitoring of tributary streams

Data collected during WY 1999 are summarized in the Lacamas Lake Restoration Program Water Quality Monitoring Report: October 1998-September 1999 Water Year.

Objective 1 was completed by Clark County Public Works (CCPW) staff in 1999. Monitoring related to Objectives 2, 3, and 4 is addressed in the main body of this report. Objective 6 was addressed as a special project during 2001, and a separate report was created for distribution to participating landowners. That report is included here as Appendix 9.

Objective 5 was not addressed. Remaining grant funds were instead focused on transitioning to post-grant work and planning for future lake and watershed management. As a new post-grant watershed management strategy is developed, interim monitoring activities will be coordinated and funded through Clark County's NPDES Clean Water program. Monitoring activities related to Objectives 5 may be pursued as part of this process.

2.0 METHODS

2.1 Quality Assurance/Quality Control

Quality Assurance/Quality Control procedures followed those outlined in the State of Washington Department of Ecology (DOE)-approved Lacamas Lake Watershed Water Quality Monitoring Program Quality Assurance Project Plan. Quality control at North Creek Analytical (NCA) laboratories was performed in accordance with the laboratory's DOE-approved quality assurance manual. Formal Chain of Custody (COC) documents were filled out for each sample set.

For purposes of data analysis, certain data points were excluded. Data points were excluded based on the following criteria:

1) any data point determined invalid based on NCA QA/QC procedures.
2) any outlying data point which, upon investigation, was found to have been compromised during sample collection or handling (e.g., sample contaminated with bottom sediment).

In cases where unexpected discrepancies occurred between original and duplicate sample values, and no obvious reason for the discrepancy was discovered, the two values were averaged.

2.2 In-Lake Sampling

2.2.1 Sample Station Location and Sampling Schedule

In-lake sampling was conducted at Site L1, shown in Figure 1. Site L1 is located in the deepest part of Lacamas Lake, and corresponds to the historical location for ambient water quality monitoring in most previous Lacamas Lake studies. Samples were collected once per month from October 1999 through September 2001, except for November 2000.

2.2.2 Field Methods

Field measurements included water temperature, dissolved oxygen, conductivity, and turbidity. Measurements were collected at one-meter intervals throughout the entire depth of the lake using a Hydrolab® DataSonde® 4 water quality instrument. Data were recorded using a Hydrolab® Surveyor® 4 logging unit. The Hydrolab® equipment was calibrated according to the manufacturer's instructions on the morning of each sampling event. In addition, all measured values were recorded on field data sheets to provide a written backup. Field data sheets were filled out using waterproof ink and included ancillary data pertaining to ambient weather conditions and any other noteworthy observations by staff.

Water samples were collected using a vertical VanDorn-style sampling bottle. Samples were collected at approximately 1m, 6m, and 17m depth during each sampling event. During periods of stratification, samples were collected one each from the epilimnion, metalimnion, and hypolimnion. One duplicate sample for each parameter was collected during each sampling event. Properly cleaned and pre-preserved bottles were supplied by the laboratory, and samples were stored on ice in coolers until delivery to the lab within 24 hours.

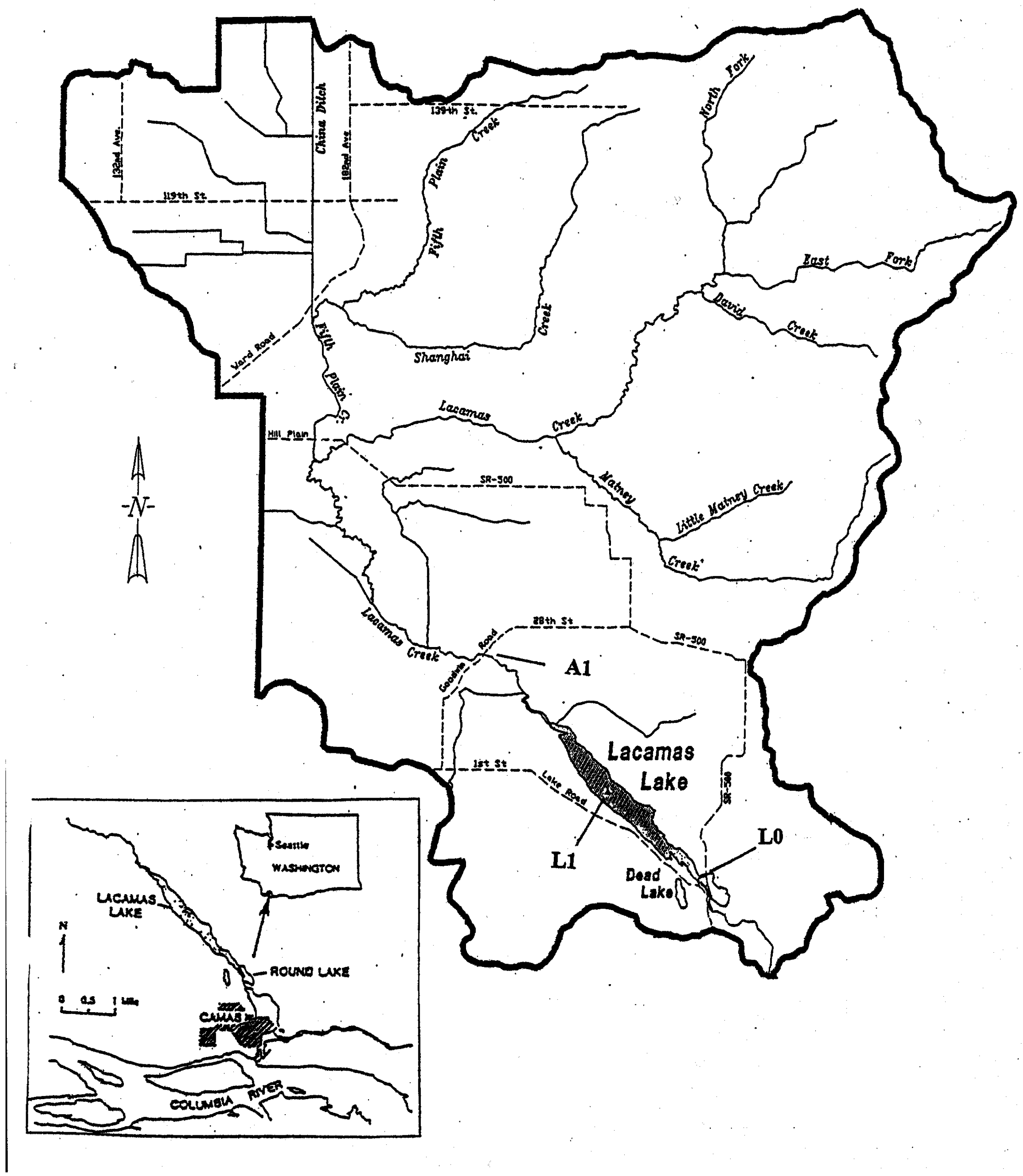


Figure 1. Lacamas Lake watershed water quality monitoring program sampling stations, during WY 1999, WY 2000, and WY 2001.

Secchi disk readings were taken from the shady side of the boat to minimize glare and to remain consistent with previous sampling protocol. Eye level for the readings was just above the side of the boat. When possible, readings were taken by two different individuals and averaged.

2.2.3 Laboratory Methods

All laboratory analyses were conducted by NCA, a DOE-accredited laboratory in Beaverton, Oregon. Water samples were analyzed for total phosphorus (TP), ortho-phosphorus (OP), total suspended solids (TSS), total Kjeldahl nitrogen (TKN), nitrite + nitrate (NO_2 + NO_3), and ammonia (NH_3). Constituents measured, analytical methods, target detection limits, precision goals, and accuracy goals are listed in Table 1.

Constituent	Method	Target Detection Limit	Precision	Accuracy
Ammonia	EPA 350.3	0.01 mg/L	20% RPD[1]	75-125%[2]
Kjeldahl Nitrogen	EPA 351.4	0.5 mg/L	20% RPD	75-125%
Nitrate/Nitrite	EPA 353.1	0.01 mg/L	20% RPD	75-125%
Orthophosphorus	EPA 300.0 A	0.01 mg/L	20% RPD	75-125%
Total phosphorus	EPA 200.7/6010A	0.01 mg/L	20% RPD	75-125%
Suspended solids	EPA 160.2	na	20% RPD	75-125%

[1]RPD = relative percent difference

[2]Acceptable range of spike recovery

Table 1. Quality assurance objectives for the Lacamas Lake watershed water quality monitoring program, WY 2000 and WY 2001.

2.3 Loading/Inlet-Outlet Sampling

2.3.1 Sample Station Location and Sampling Schedule

Inlet and outlet samples were collected at sites A1 and L0, respectively, as shown in Figure 1. Site A1 is located on Lacamas Creek immediately upstream of the Goodwin Rd bridge (#172). Site L0 is located in the narrow channel between Lacamas Lake and Round Lake, immediately east of the State Route 500 bridge. These two sites correspond to the historical location of sites A1 and L0 in previous sampling programs.

Inlet samples were collected with a Sigma® 900MAX All-Weather Refrigerated Sampler. Outlet samples were collected with a Sigma® 900MAX Portable Sampler.

Inlet samples were collected during 16 rainfall events during WY 2000. In addition, 45 grab samples were collected during between-storm periods. A total of 137 inlet samples were analyzed during WY 2000.

During WY 2001, inlet samples were collected during 8 rainfall events in addition to 42 between-storm samples. A total of 86 inlet samples were analyzed during WY 2001.

Outlet samples were generally collected every 7-10 days, with occasional higher sampling intensities during selected storm periods in WY 2000. A total of 83 outlet samples were analyzed during WY 2000, and 38 during WY 2001.

2.3.2 Field Methods

The Sigma® sampler at Site A1 continuously recorded rainfall, stage, dissolved oxygen, conductivity, pH, and water temperature at one hour intervals throughout the sampling period. A stage vs. discharge curve was programmed into the sampler based on equations developed by Glen Dorsey of CCPW, allowing the sampler to provide hourly discharge data in addition to stage data.

Stage was recorded using a pressure transducer mounted in an off-channel stilling well. Water samples, dissolved oxygen, conductivity, pH, and water temperature were obtained from approximately the mid-point of Lacamas Creek via intake tubing and water quality sensors mounted in a protective manifold. Sensors were periodically calibrated according to manufacturer's instructions. Calibration intervals were contingent on safe stream access and predicated on excessive sensor drift as determined through cross-checking sensor readings with Hydrolab® equipment. Rainfall was recorded with an electronic tipping-bucket rain gage located on a telephone pole in an exposed area approximately 50 feet from the sampler.

The sampler was programmed to collect water samples at varying intervals through storm events, after being triggered by rainfall. Generally, the first 12-14 samples were collected at 3-hour intervals and the remaining samples at 5-hour intervals. Trigger points for the sampler varied somewhat depending on antecedent conditions, but were generally set so the sampler would collect a single sample any time 0.50" of rain occurred in any 24 hour period. A full 24-bottle storm sampling cycle was generally triggered when 0.75" of rain fell within a 24 hour period. Between-storm samples were collected using the sampler's manual sampling mode.

On 7 occasions during WY 2000 and 5 occasions during WY 2001, water samples were collected simultaneously from within the protective manifold and immediately outside the manifold in an area of unimpeded flow to assess whether the manifold introduced a sampling bias. Three "multiple-grab" comparison sample sets were also collected. On these occasions, two grabs were collected in immediate succession using the manual mode of the Sigma® sampler, while a third sample was collected by hand from the thalweg adjacent to the Sigma® intake manifold.

Beginning on 19-April, 2001, the intake manifold was modified so that the water intake tube extended outside of the manifold. As an additional measure, staff began collecting two samples with the Sigma® equipment during each grab event. The first grab was discarded and the second grab retained for analysis. This more closely simulates the pre-purge and sample line rinse performed by the Sigma® equipment during automatic storm sampling.

On 3 occasions during WY 2000, stage readings from the Sigma® equipment were compared to stage readings from a pre-existing CCPW Stevens® float gage at the same location to confirm consistent measurement.

On 1-May, 2000, the CCPW Stevens® gage was discontinued and a different Stevens® chart recorder was placed in the stilling well of the Site A1 station to provide a backup for the Sigma® equipment. Including the initial calibration period, stage readings from the Sigma® equipment and the Stevens® recorder were compared on 6 occasions between 1-May 2000 and 27-September 2001 to confirm consistent measurement.

Stage, rainfall, pH, dissolved oxygen, conductivity, and water temperature were not measured at Site L0. Water samples were collected via intake tubing suspended approximately three feet from the channel bottom near the center of the 10' deep channel between the two lakes. Sampling was manually triggered. On five occasions during WY 2001, quality assurance samples were collected simultaneously with the Sigma® unit and with a VanDorn-style sampling bottle from the SR500 bridge approximately 50 feet upstream of the Sigma® unit.

2.3.3 Laboratory Methods

All laboratory analyses were conducted by NCA. Water samples were analyzed for TP and TSS. Constituents measured, analytical methods, target detection limits, precision goals, and accuracy goals are listed in Table 1.

2.4 Data Analysis

2.4.1 Pollutant Loading Estimates

The following rules and procedures were used in generating pollutant load estimates:

Data were periodically downloaded from the Sigma® sampler at Site A1 using a Sigma Data Transfer Unit II® logging unit. Twenty-eight downloads were performed during WY 2000, and 15 during WY 2001. Each downloaded data set included rainfall, stage, flow, dissolved oxygen, pH, conductivity, and water temperature data at one-hour intervals.

For each water year, the individual download periods were combined into a single annual database using Sigma Insight® software. From this database, an annual hydrograph was generated, showing stage and conductivity data over time. The complete hydrographs are contained in Appendix 1. Additionally, the entire Insight® databases were converted to Microsoft Excel® spreadsheets, which were utilized for loading calculations. Laboratory data points for TP and TSS were manually entered into the spreadsheets at the corresponding sample time.

Laboratory reporting limits varied somewhat for each sample set. Censored (below laboratory reporting limit) laboratory data were entered as ½ of the corresponding reporting limit.

Concentrations were estimated for all hourly time periods not corresponding to an actual laboratory concentration value, as follows:

Laboratory concentration data were recorded for the nearest hour, and remained constant through all one-hour intervals until a new laboratory data point was recorded. For example, assume samples were taken at 1:00 p.m. and again at 4:00 p.m. on the same day. The laboratory TP concentration (mg/L) for the 1:00 p.m. sample = .150 and for the 4:00 p.m. sample = .200. The data as entered in the hourly database would be:

1:00 TP = .150
2:00 TP = .150
3:00 TP = .150
4:00 TP = .200
5:00 TP = .200

On a few occasions, data gaps of a few hours occurred between data download periods. In these instances, the missing data points were filled in by interpolating between the two end points of existing data.

On one occasion, data was lost due to memory failure in the data logger during download to the desktop computer. For that period (23 December 1999- 7 January 2000), stage and flow data were filled in with data from the Stevens® gaging station located at Goodwin Road. The Stevens® data were adjusted by +0.42 ft to account for differences between the datum of the two gages and ensure they remain consistent with data generated by the Sigma sampler.

The stage vs. discharge equations used at Goodwin Road were developed by Glen Dorsey based on the pre-existing Stevens® gage datum. Due to installation constraints, the Sigma® gage datum did not match the Stevens® datum. Comparison samples during WY 1999 revealed that the average difference between the

Stevens® gage and the Sigma® gage during that year was 0.42 ft. To account for this difference, 0.42 ft was added to all stage recordings from the Sigma® sampler.

Stage-discharge equations were updated during early 2000. The new equations were back-applied as of January 1, 1999. Appendix 2 contains the adjusted stage and flow data programmed into the sampler and the resulting equations used to calculate streamflow during WY 2000 and WY 2001.

Streamflow was multiplied by pollutant concentration for each one hour period, and these periods were summed to arrive at an annual loading estimate. The final page of a loading spreadsheet may be found at the end of Appendix 1 as a reference.

2.4.2 In-load vs. Out-load comparison methods

"Out-load is the amount of TP and TSS leaving the lake at Site L0. Out-load estimates were generated using pollutant concentration data from Site L0. Rules and procedures were identical to those used for in-load estimates. However, out-load estimates must be viewed with added caution due to the unknown impact of dam operations on lake out-flow. Discharge data from Lacamas Lake was not available during the sampling period. As a result, out-load estimates had to be calculated based on the assumption that inflow discharge at Site A1 equals outflow discharge at Site L0 for any given point in time. This assumption is known to be false due to dam operations, fluctuating lake storage and inflow, and variable lag time as water flows from Site A1 to Site L0. The overall effect of these conditions on the out-loading estimates is unknown, but is assumed to be minimal over the course of a year.

2.4.3 Statistical analyses of long-term in-lake data set

Statistical analyses were performed using WQStat Plus® software and the data set for Lacamas Lake (Site L1) from 1984-2001. Principle analyses included annual box-and-whisker plots and the Seasonal Kendall test for long-term trends. The Seasonal Kendall test was chosen because it statistically removes the effect of seasonal cycles prior to testing for trends. For any months with multiple data points, the data points were averaged (arithmetic mean) prior to analysis to comply with the statistical assumption of one data point per month required for the Seasonal Kendall tests. As with most water quality data, Lacamas Lake data exhibit seasonal patterns which can confound some trend tests.

It should be noted that there are limitations in the test for long-term trend. Data collection methods, laboratory detection limits, and equipment have varied to some extent over the course of the program since 1984. The effect of these differences is unknown.

In addition, the existence of data gaps necessitates some assumptions about the applicability of the trend test. Since the Seasonal Kendall test is a nonparametric test, the existence of data gaps is permitted under the basic assumptions of the test. However, the Lacamas data set includes periods of several years with no data as well as several smaller periods of missing data ranging from one to six months. Based on a literature review and consultation with the WQStat Plus® technical assistance staff, it is assumed that the length of data gaps is irrelevant to the effectiveness of the Seasonal Kendall test for trend. Regardless, the detected trends should be interpreted cautiously since the overall data set is not large and other factors, such as annual weather variations, are not accounted for.

Trend analyses were performed on both the 1984-2001 and 1991-2001data sets. Trend tests were performed for the epilimnion only. Data from the metalimnion and hypolimnion are not extensive enough to perform the test. Generally, only trend tests indicating a trend at the 90% confidence interval or greater are addressed in the results section. A 90% confidence level indicates that there is a 90% chance that the indicated trend actually exists, or a 10% chance that the indicated trend is erroneous. Results for all other trend tests are included in Appendix 7.

Annual box-and-whisker plots are included for selected parameters. To insure reasonable comparability, any years having fewer than six data points are not included in the box-and-whisker plots. It should be noted that box-and-whisker plots constructed in WQStat Plus®, by default, must be arranged by calendar year (Jan-Dec). Most other data analyses in this report are based on water year (Oct-Sept). Annual box-and-whisker plots provide a quick way to compare the distribution and variability of data at a station over a period of years.

Each plot depicts the median as the centerline and the interquartile range (25th and 75th percentiles) as the ends of the box. The whiskers extend to the maximum and minimum values, and the plus sign represents the sample mean.

3.0 Results

3.1 QA/QC Sampling

3.1.1 In-lake, In-stream, and Lab QA/QC

Laboratory concentration data for lake duplicate samples are included with the lake data in Appendix 3. QA/QC data were reviewed by NCA prior to delivery to the LLRP. LLRP staff also reviewed the NCA QA/QC data for consistency. NCA QA/QC data and Chain of Custody documents are not included in this report, but are on file and available upon request from the LLRP.

Laboratory and field data in Appendix 3 include all measured values. For purposes of data analysis and reporting, certain data points were excluded or averaged according to the procedures listed in section 2.1. The adjusted values are found in the WQStat Plus® database in Appendix 6.

Dissolved oxygen and pH data collected by the Sigma® equipment at Site A1 were not used due to excessive sensor drift throughout the sampling period. Buildup of organic material on the sensors occurred very rapidly, confounding efforts to keep the sensors calibrated. Staff concluded that keeping the sensors adequately maintained would not be feasible within budget limitations.

3.1.2 Thalweg Comparison Samples

Inlet

TP and TSS data for thalweg comparisons were collected on 7 occasions during WY 2000 and 5 occasions during WY 2001. These data are contained in Appendix 4.

On nine occasions the TP concentration measured inside the manifold was higher than the thalweg, while on three occasions the thalweg concentration was higher. For TSS, on 10 occasions the concentration inside the manifold was higher than the thalweg, on one occasion the thalweg concentration was higher, and on one occasion the samples were equal.

Results of the “multiple-grab” comparisons are also found in Appendix 4. On each of the three sample dates, the first Sigma® grab always had a higher concentration of TP and TSS than the second Sigma® grab. The concentration in the second Sigma® grab was always closer to the concentration of the thalweg sample.

These QA/QC data pointed to a possible build-up of fine sediment within the manifold, which appeared to be re-suspended during the pre-sample purge cycle. This newly suspended sediment could potentially be drawn into the sample bottle during manual-mode grabs, affecting the measured concentrations of both TSS and TP. It is unlikely that this issue affected samples collected automatically during storm events because of the “rinse” cycle performed by the machine prior to collecting a sample. **However, the tendency for measured concentrations of TP and TSS to be higher inside the manifold during manual-mode grabs could result in overestimation of the pollutant load.**
Based on the QA/QC results during WY 2000 and 2001, the protective manifold and sampling protocol have been modified as described in section 2.3.2.

Outlet

TP and TSS data for thalweg comparisons at the station LO were collected on 7 occasions during WY 2000 and 4 occasions during WY 2001. For TP, the concentration of the Sigma® sample was greater than the thalweg on eight occasions, and less than the thalweg on 3 occasions. For TSS, the concentration of the

Sigma® sample was greater than the thalweg on 7 occasions, and equal to the thalweg on 4 occasions. However, on nearly all occasions, the difference between Sigma® and thalweg samples for both parameters were negligible. Therefore, no modifications were necessary and it was assumed that data collected using the Sigma machine were representative of the stream at the time of sampling.

3.1.3 Gage Comparisons

Stage comparison data were collected from the pre-existing Stevens® gage and the Sigma® gage at Site A1 on 3 occasions during WY2000. These data are found in Appendix 5.

Due to different setup locations and datum (zero point), the pre-existing Stevens® gage stage values were known to be uniformly lower than the Sigma® values. Samples were collected to insure a consistent difference between the two gages.

Stevens® values for a given sample time were subtracted from the corresponding Sigma® value. The difference values were averaged to arrive at a mean difference over the sampling period. The difference between gages ranged from 0.46 ft. to 0.50 ft. The mean difference between the two gages was 0.48 ft. The mean difference in WY 1999 was similar at 0.42 ft. Only three comparison values were collected during the 2000 water year, for two reasons. First, more frequent comparisons during the previous year demonstrated adequate consistency between the two gages. Only occasional spot-checking was planned for the second year. Second, the original Stevens® gage was inactivated by CCPW during early 2000, leaving the Sigma® gage as the primary gage at Goodwin Rd.

Subsequently, a different Stevens® strip-chart recorder was installed as a backup to the Sigma® gage at Site A1, and is located in the monitoring station stilling well. This Stevens® recorder was installed with a datum 0.09 ft higher than the Sigma® gage. Appendix 5 contains the results of 6 comparisons between the Sigma® and Stevens® gages during WY 2001. The difference ranged from 0.07 ft to 0.11 ft, and averaged 0.09 ft., indicating good consistency between the gages.

3.2 Weather

Generally, WY 2000 and WY 2001 were characterized by above-average temperatures and below-average precipitation. Measurements recorded approximately one quarter mile southwest of Lacamas Lake by Mr. Reuben Bafus indicate that precipitation for WY 2000 was 48.43 inches, or 6.39 inches below the 44-year average. In WY 2001, total precipitation was 34.02 inches, or 20.20 inches below the 45-year average. According to Mr. Bafus, annual precipitation of 34.02 inches represents the lowest annual precipitation recorded during the past 45 years.

Long-term departures from normal monthly precipitation and temperature at the NOAA Washington State Climatological Data stations in Battle Ground and Vancouver are shown in Figure 2 and Figure 3.

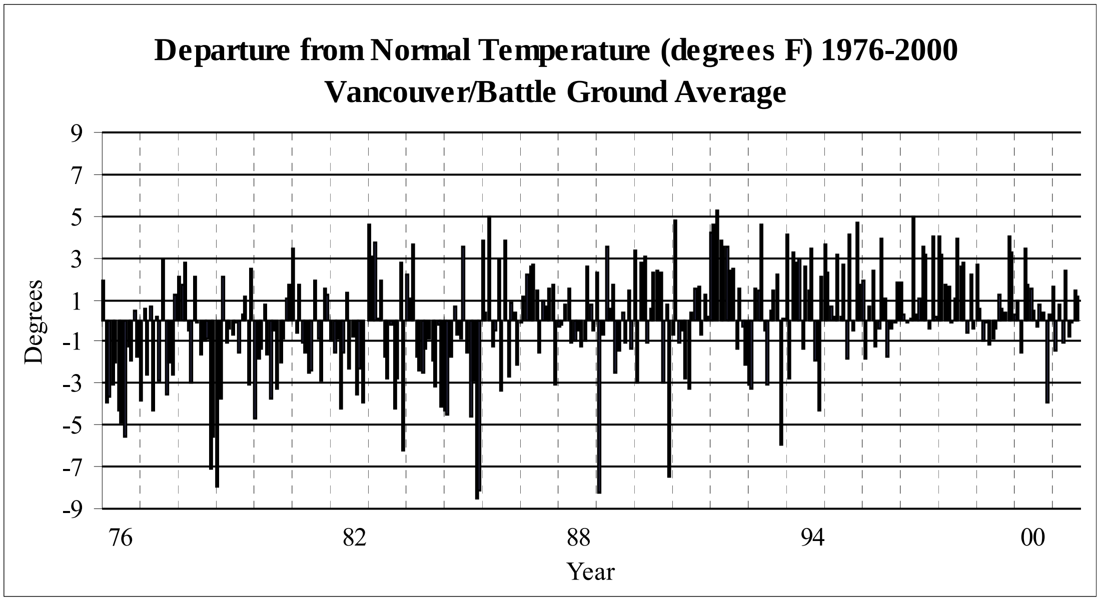


Figure 2. Departures in monthly temperature from long-term average (1951-1980) conditions. Data are from N.O.A.A. Washington State Climatological Data for Battle Ground and Vancouver, Washington. Battle Ground and Vancouver station data are averaged.

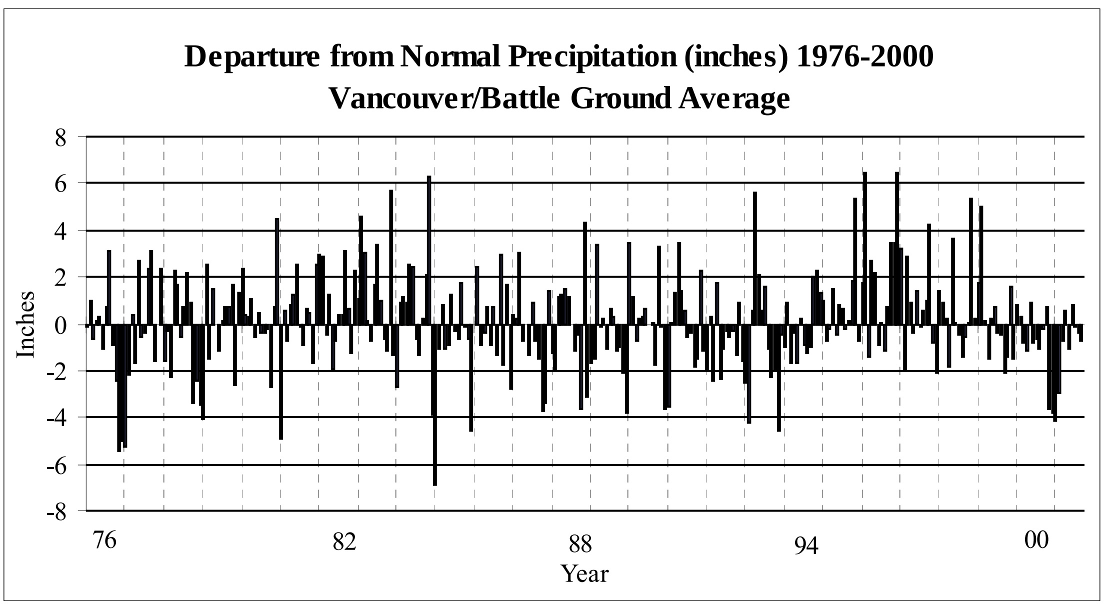


Figure 3. Departures in monthly precipitation from long-term average (1951-1980) conditions. Data are from N.O.A.A. Washington State Climatological Data for Battle Ground and Vancouver, Washington. Battle Ground and Vancouver station data are averaged.

3.3 In-Lake

Appendix 3 contains the WY 2000 and WY 2001 in-lake data from Site L1. The long-term database created for statistical use in WQStat Plus®, which includes data collected at Site L1 from 1983-2001, is contained in Appendix 6.

Summaries of WY 2000 and WY 2001 data, results from the Seasonal Kendall trend test, and annual box-and-whisker plots are presented in the following subsections.

3.3.1 Water Temperature/Dissolved Oxygen

Figure 4 and Figure 5 show vertical profiles of water temperature and dissolved oxygen at site L1 during WY 2000 and WY 2001, respectively. Temperature and dissolved oxygen exhibited patterns similar to previous years.

After a fall and winter period characterized by a fully mixed, isothermal, and well-oxygenated water column, thermal stratification and hypolimnetic dissolved oxygen depletion began concurrently during mid-spring. Throughout the summer and early fall, the lake exhibited strong thermal stratification with a pronounced thermocline at approximately 3-6 meters. Dissolved oxygen depletion in the hypolimnion increased in severity through this period. At its most severe, during late July and August, oxygen levels dropped to near zero below 4 meters. By mid-September, decreasing air temperatures and wind-mixing began to erode the thermal stratification, characterized by a sinking of the thermocline layer and a gradual recovery of dissolved oxygen concentrations until full mixing in late fall.

Figure 6 shows a downward trend (-0.08 mg/L/yr) in epilimnetic dissolved oxygen since 1984, and a slightly more pronounced trend (-0.12 mg/L/yr) since 1991. These trends are significant at the 90th and 95th percentile, respectively.

Peak surface water temperatures were 22° C in July 2000 and 23° C in July 2001. Temperatures near the bottom were consistently around 10° C during the spring, summer, and fall, dropping to between 5° and 8° C throughout the lake during the fully mixed winter period.

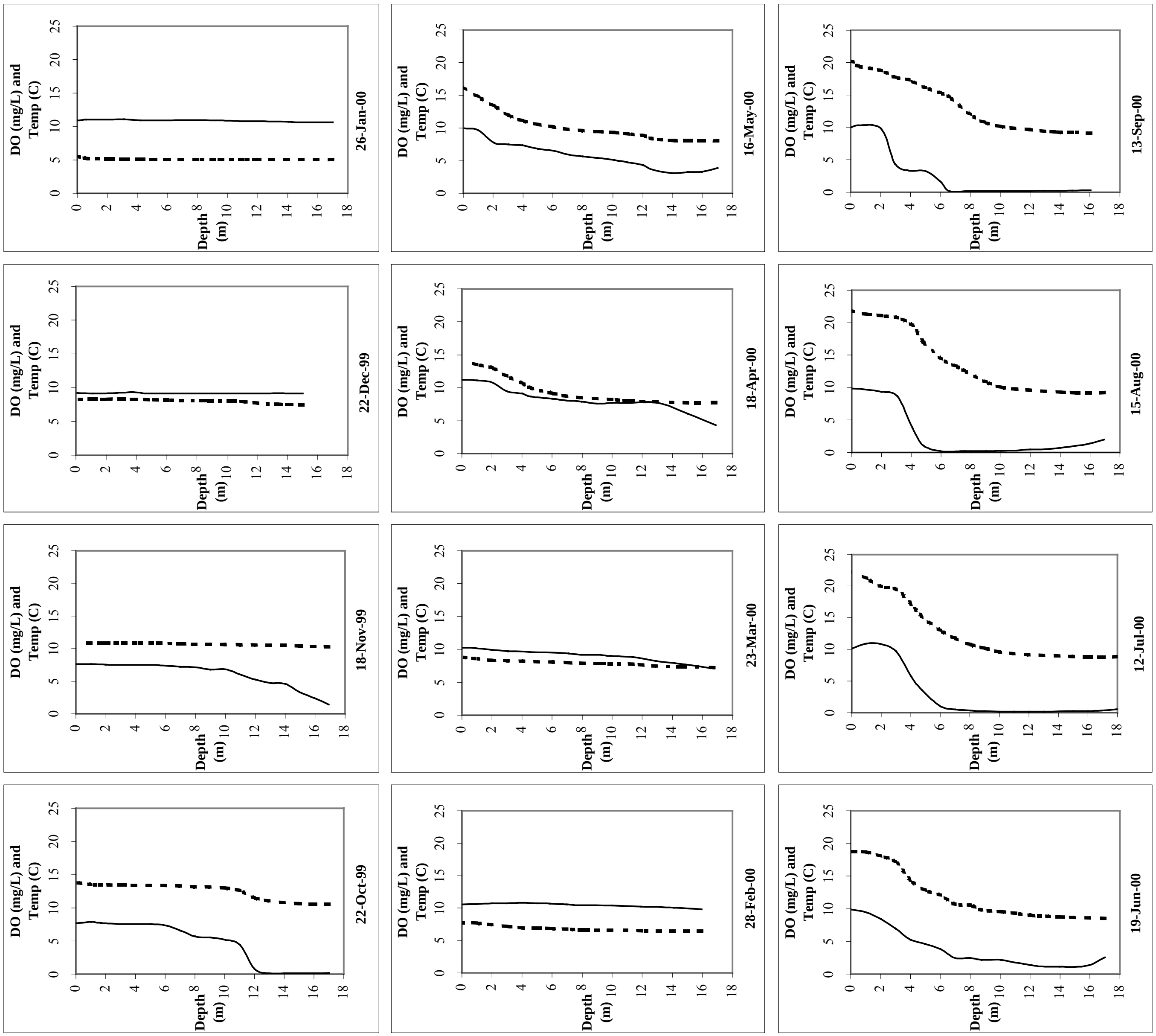


Figure 4. WY 2000 temperature and dissolved oxygen profiles, Lacamas Lake site L1.

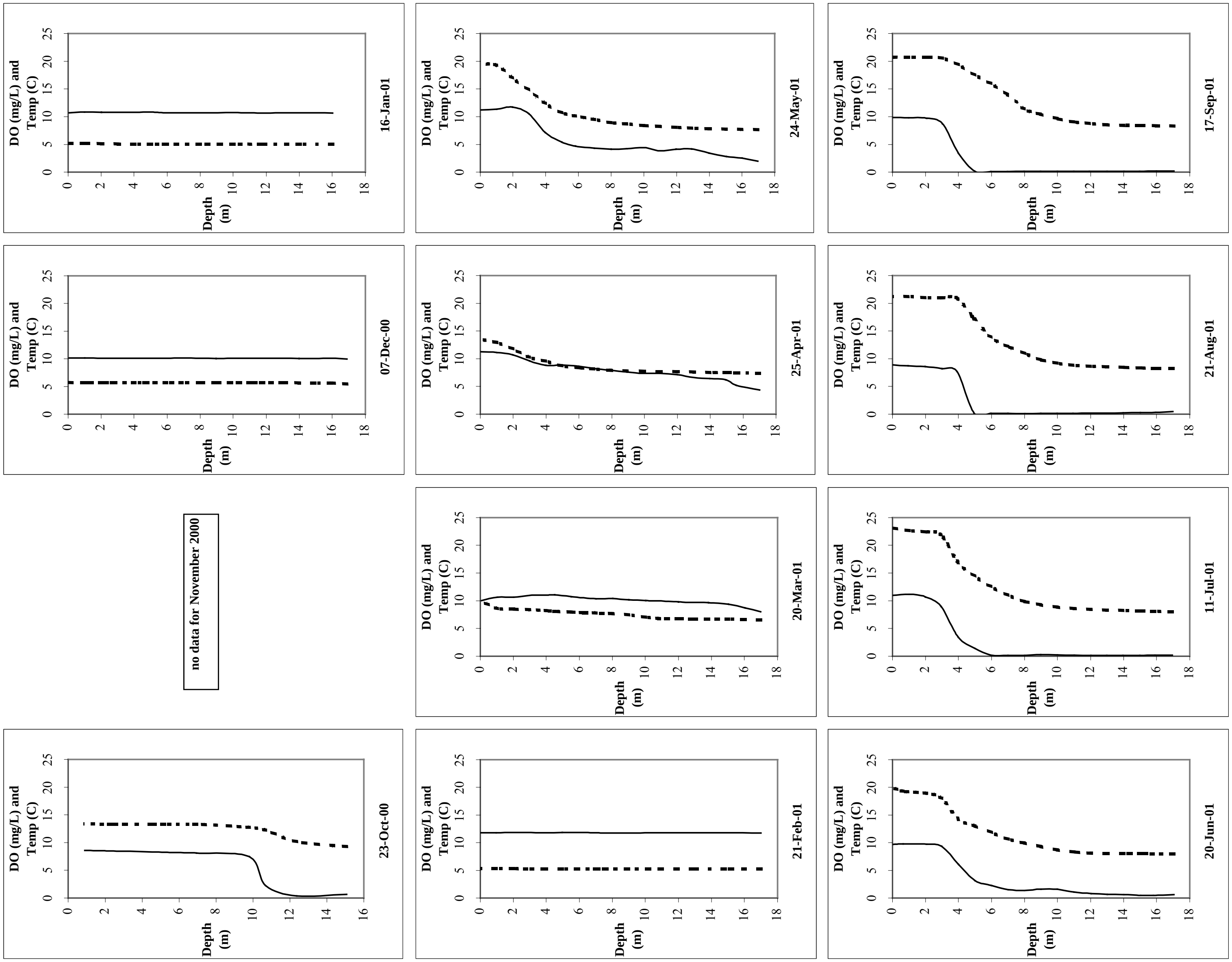
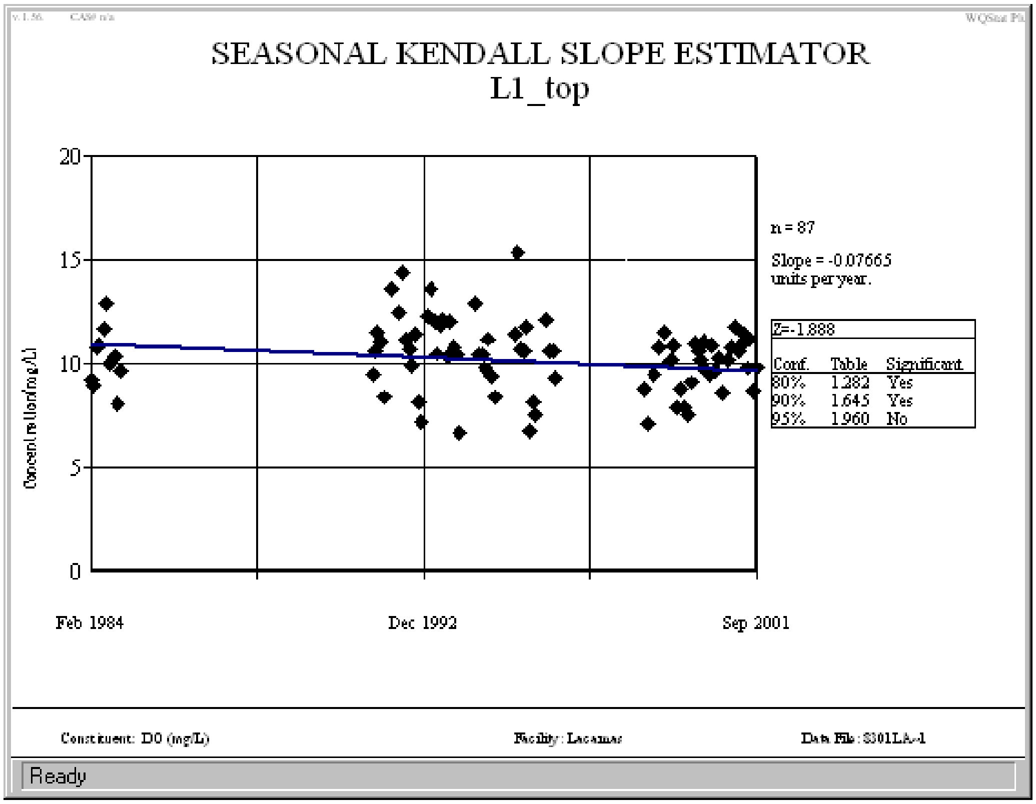


Figure 5. WY 2001 temperature and dissolved oxygen profiles, Lacamas Lake site L1.



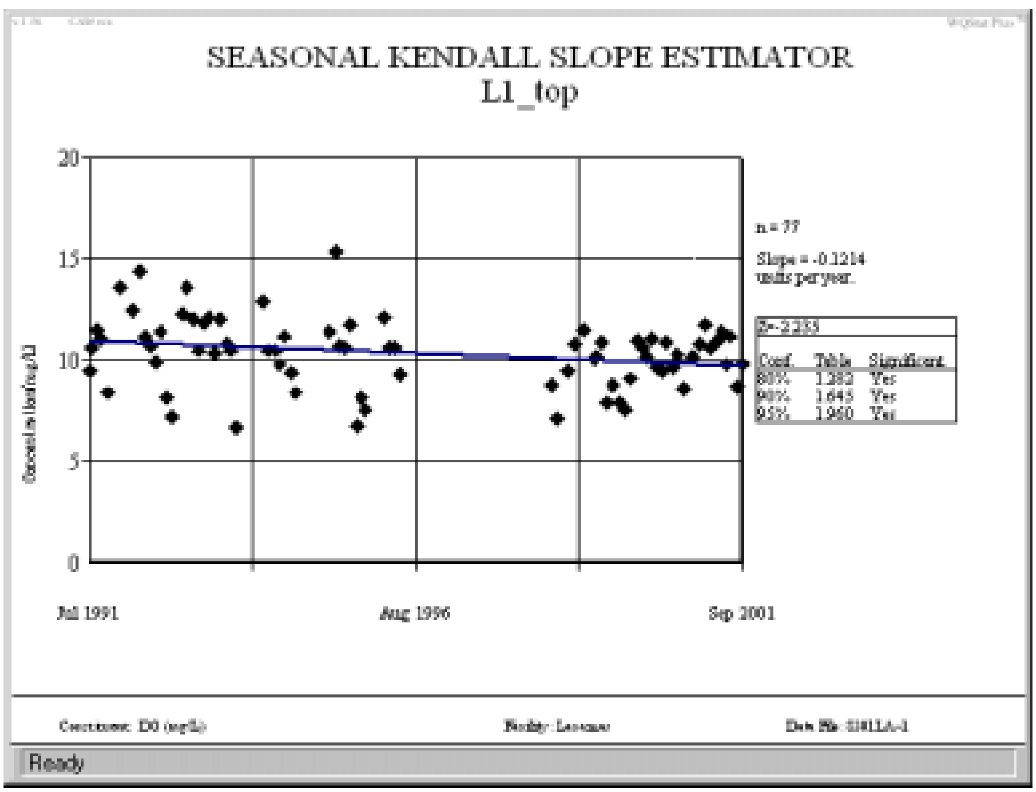


Figure 6. Seasonal Kendall test for trend, Site L1 epilimnion, dissolved oxygen 1984-2001 and 1991-2001.

3.3.2 Secchi Disk Transparency

A mean secchi transparency of <2 meters meets the EPA criterion for eutrophic classification. In 1984, at the beginning of the Lacamas Program, mean secchi depth was 1.3m. By comparison, mean secchi disk transparency for WY 2000 was 1.3 meters, and WY 2001 1.4 meters. These results are similar to WY 1999 (1.5 meters) and previous years. However, during the June 2001 sampling event secchi depth was measured at nearly 3 meters. This was the deepest secchi reading measured in the past three water years.

3.3.3 pH- Epilimnion

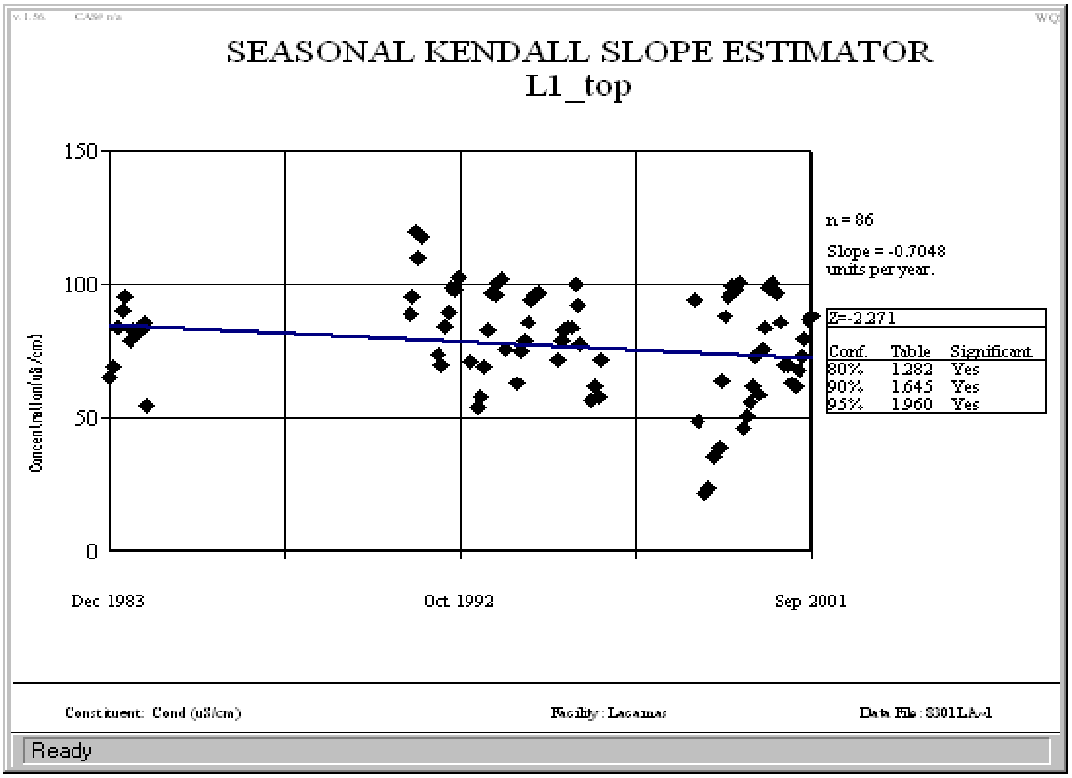
Due to recurring problems with the Hydrolab® pH sensor, lake pH readings were not recorded during WY 2000 and WY 2001.

3.3.4 Conductivity- Epilimnion

Conductivity exhibited similar seasonal patterns as in previous years. Surface conductivity readings were generally highest from late summer to mid-winter, and lowest from late winter through spring. Values ranged from 46 uS/cm to 101 uS/cm during WY 2000 and 62 us/cm to 97 uS/cm during WY 2001. As shown in Figure 7, a slight decreasing trend (-0.70 uS/cm per year) is apparent between 1984 and 2001. Since 1991, a more pronounced decreasing trend (-0.93 uS/cm per year) has been evident (Figure 7). Both of these trends are significant at the 95% confidence level.

3.3.5 Total Suspended Solids- Epilimnion

Total Suspended Solids concentrations were consistently at or below laboratory detection limits (5-10 mg/L) throughout WY 2000 and WY 2001. Historical data tend to follow the same pattern, although spikes in TSS up to 20-30 mg/L have been measured in some years, as shown in the annual box-and-whisker plots (Figure 8). It is likely that the timing of sampling events relative to algae blooms and large storm inflows has a significant impact on measured TSS concentrations. Therefore, the absence of spikes in TSS concentration through the current sampling period is likely due to an absence of sampling during periods of higher TSS concentration rather than an actual reduction in lake TSS. Because of this uncertainty, no attempt has been made to determine trends in TSS.



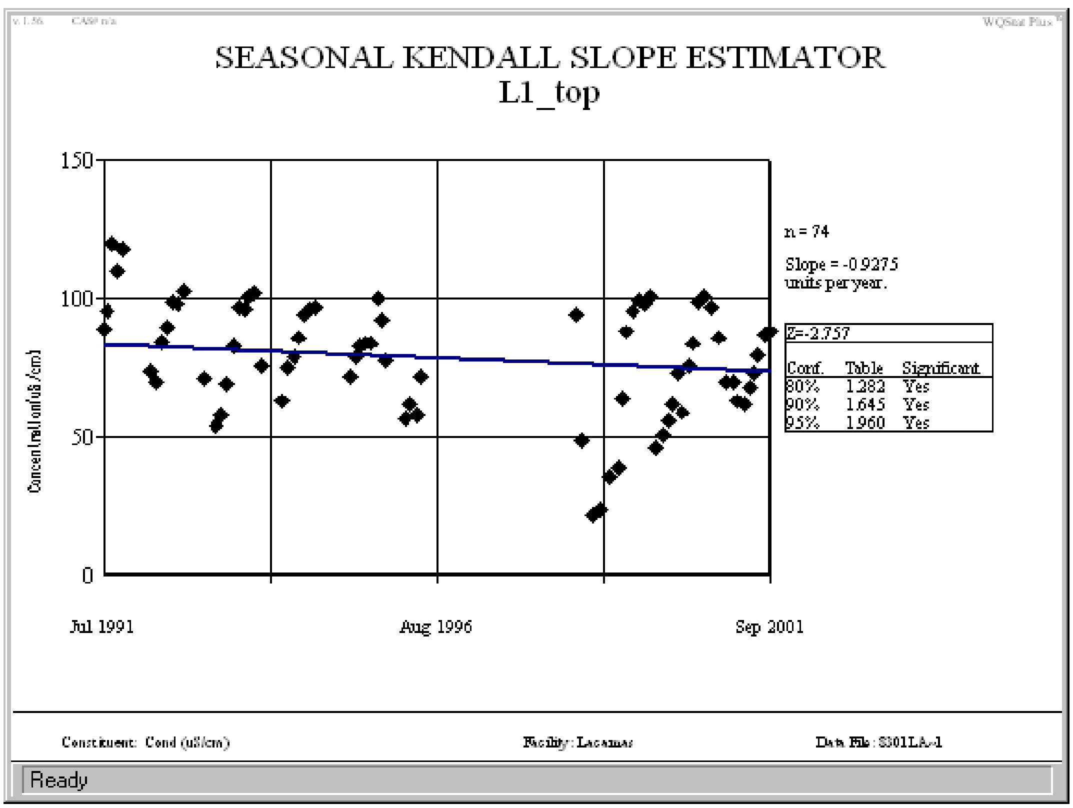


Figure 7. Seasonal Kendall test for trend, Site L1 epilimnion, conductivity 1984-2001 and 1991-2001.

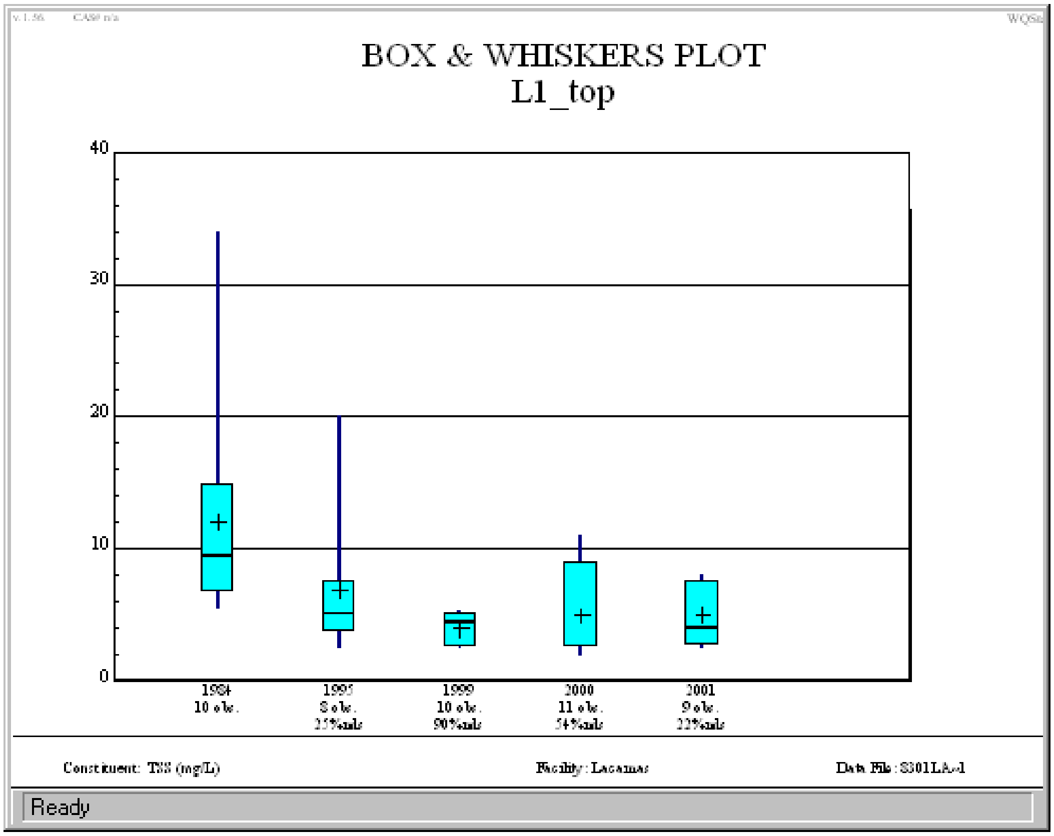


Figure 8. Annual box-and-whisker plots, Site L1 epilimnion, total suspended solids.

3.3.6 Phosphorus- Epilimnion

A mean epilimnetic TP value of 0.025 mg/L or higher exceeds the EPA criterion for lakes, and a mean value of 0.030 mg/L or higher is generally indicative of eutrophic lake conditions. Mean epilimnetic TP during WY 2000 was 0.031 mg/L, ranging from <0.010 mg/L during January 2000 to 0.053 mg/L during February 2000. During WY 2001, mean epilimnetic TP was 0.029 mg/L, ranging from 0.019 mg/L in July to 0.045 mg/L in March. By comparison, mean epilimnetic TP in 1984 was 0.070 mg/L.

Figure 9 contains the annual box-plots for epilimnetic TP. In Figure 10, the Seasonal Kendall test indicates a slight decreasing trend in epilimnetic TP (0.0009 mg/L per year) since 1984 at the 95% significance level. However, for the time period since 1991 (Figure 10) there has been no apparent trend in TP concentration.

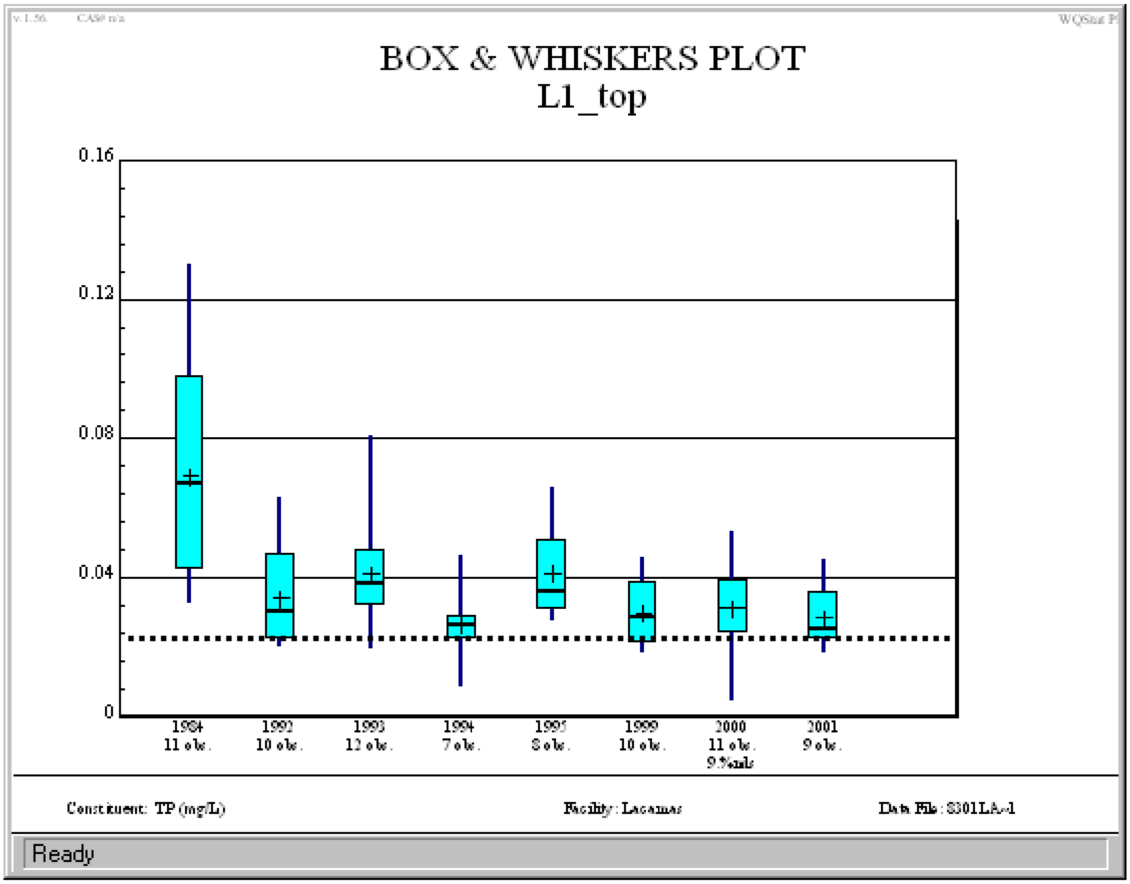
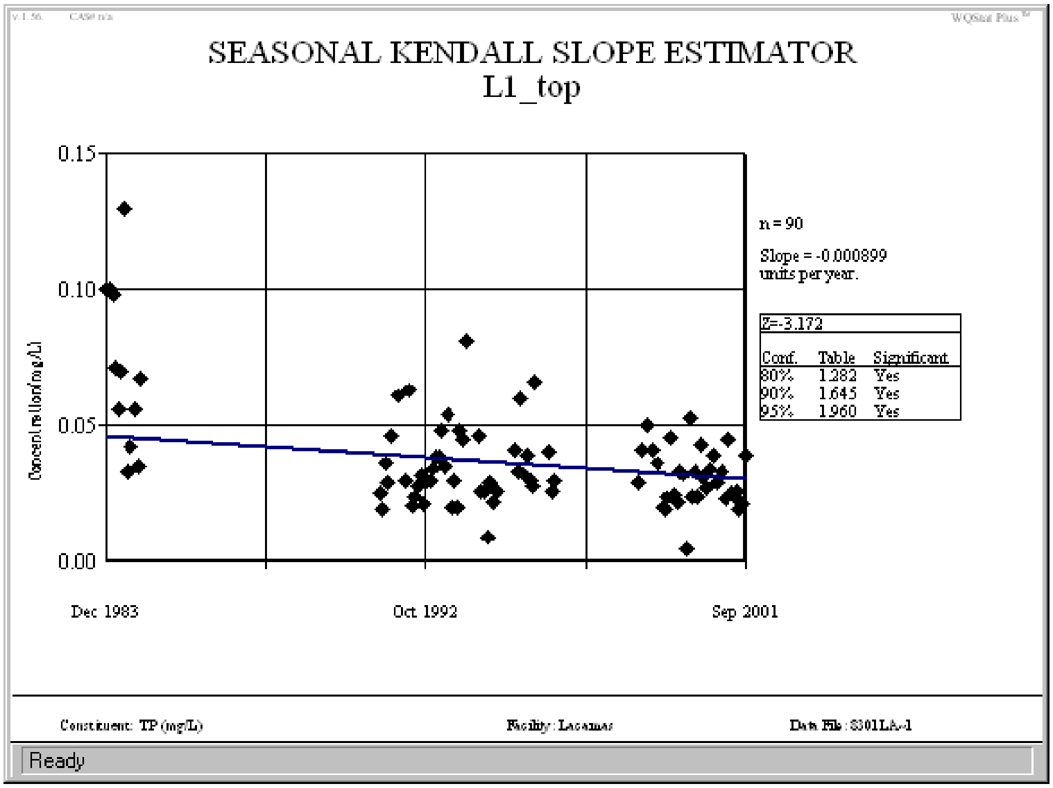


Figure 9. Annual box-and-whisker plots, Site L1 epilimnion, total phosphorus. Dashed line indicates EPA lake TP criterion of 0.025mg/L.

WY 2000 orthophosphorus in the epilimnion ranged from <0.002 mg/L in October 2000 to 0.024 mg/L in December 1999 and September 2000. During WY 2001, values ranged from <0.005 mg/L in May 2001 to 0.020 mg/L in February 2001. As was the case in water year 1999, during the winter high-flow season a high percentage of the phosphorus measured in the epilimnion was in the OP form, especially during WY 2000.

Figure 11 depicts the results of trend analyses for OP. For the 1984-2001 period, the Seasonal Kendall indicates no trend in OP concentration. However, since 1991 the data indicate an increasing trend in OP (+0.0005 mg/L/yr) at the 90% confidence level.



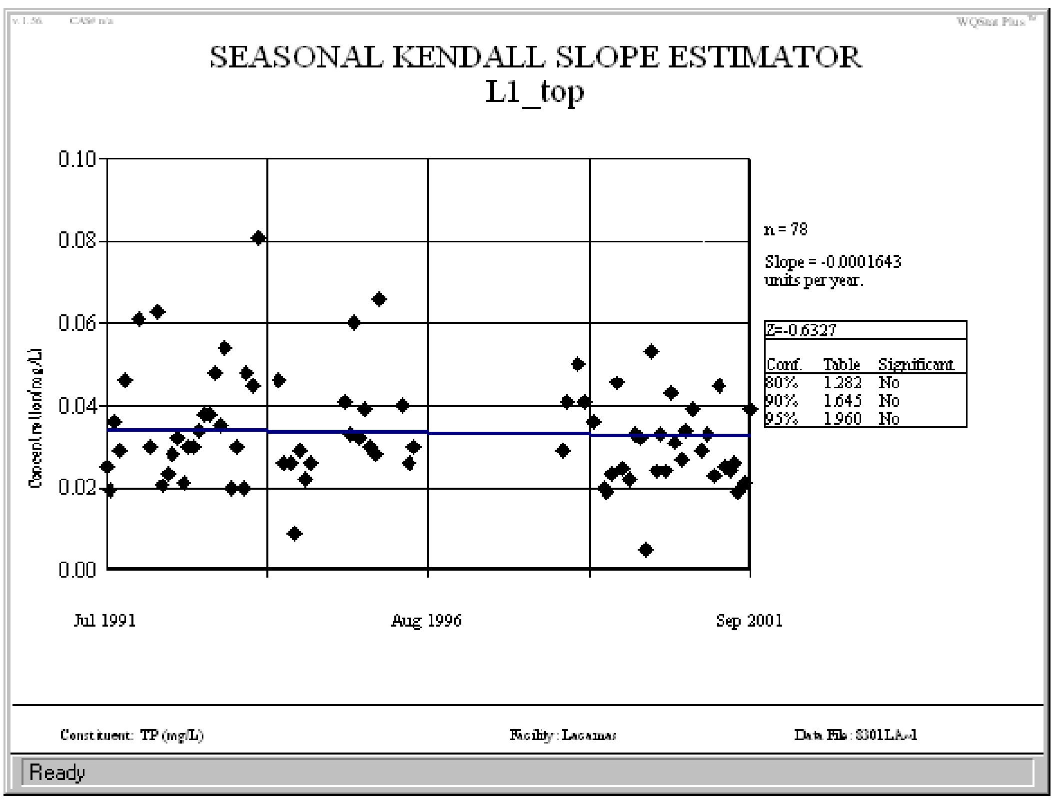
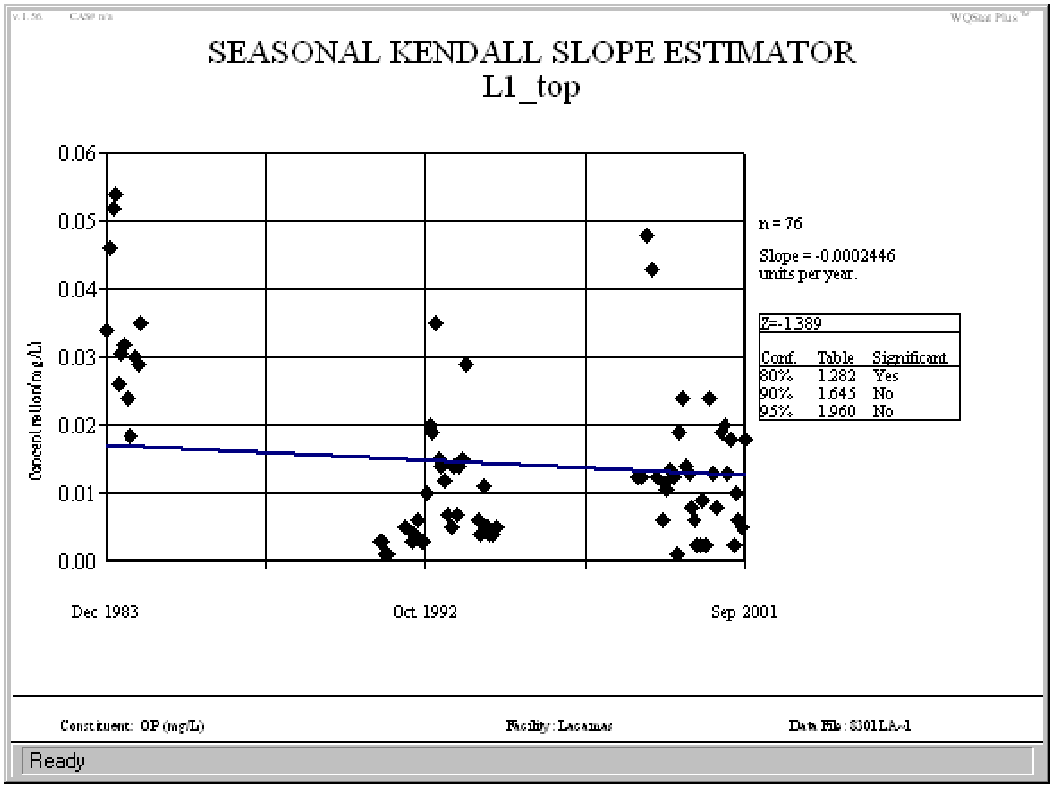


Figure 10. Seasonal Kendall test for trend, Site L1 surface, total phosphorus, 1984-2001 and 1991-2001.



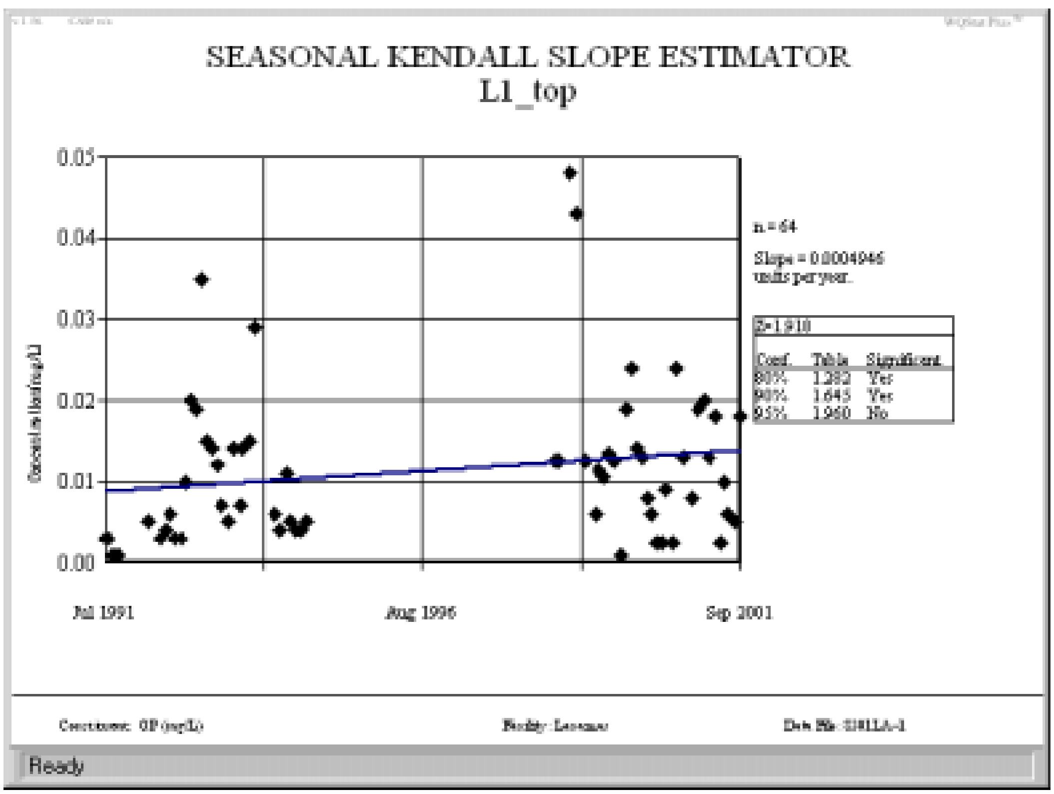


Figure 11. Seasonal Kendall test for trend, Site L1 surface, ortho-phosphorus, 1984-2001 and 1991-2001.

3.3.7 Nitrate- Epilimnion

WY 2000 nitrate concentration in the epilimnion ranged from 0.040 mg/L in September 2000 to 1.2 mg/L in April 2000. During WY 2001, concentrations ranged from <0.005 mg/L in September 2001 to 1.570 mg/L in March 2001. Nitrate levels remained near 1 mg/L throughout winter and spring, falling off sharply through the summer months. A general pattern of nitrate peaks during winter and substantial depletion during late summer is consistent with historical Lacamas Lake sampling results.

Annual box-and-whisker plots indicate a possible increase in the variability and range of nitrate values since 1984 (Figure 12). However, as shown in Figure 13, the Seasonal Kendall test does not indicate a significant trend in nitrate concentration for either of the time periods tested.

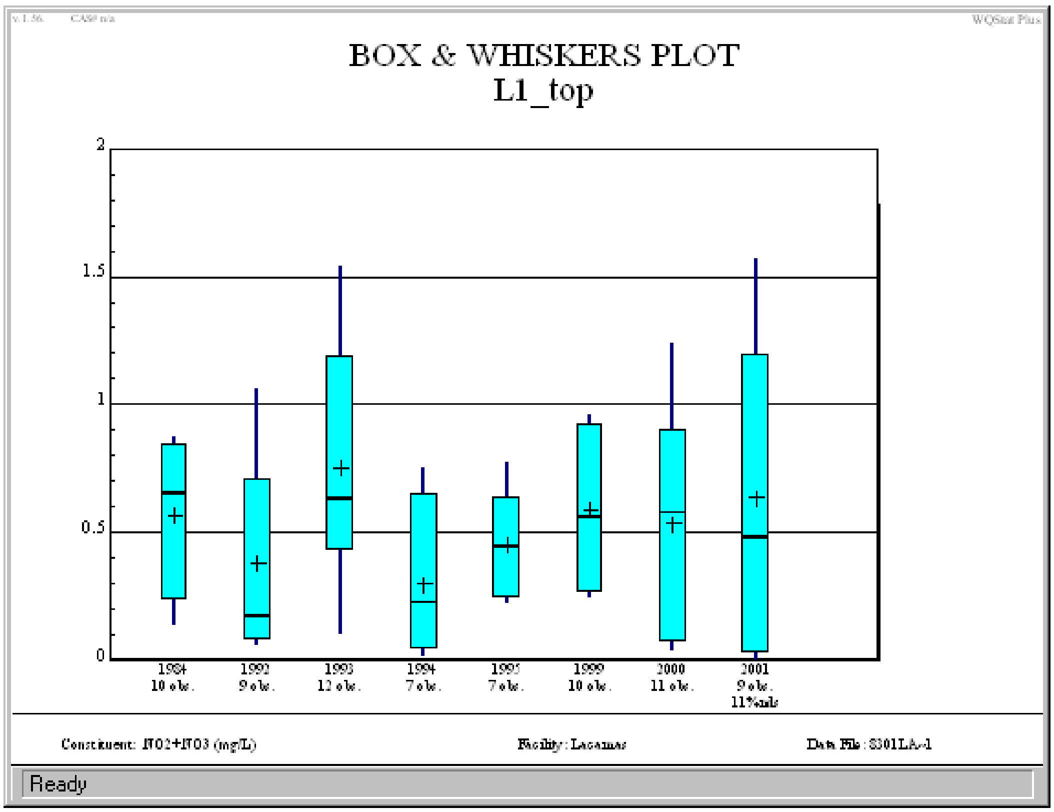
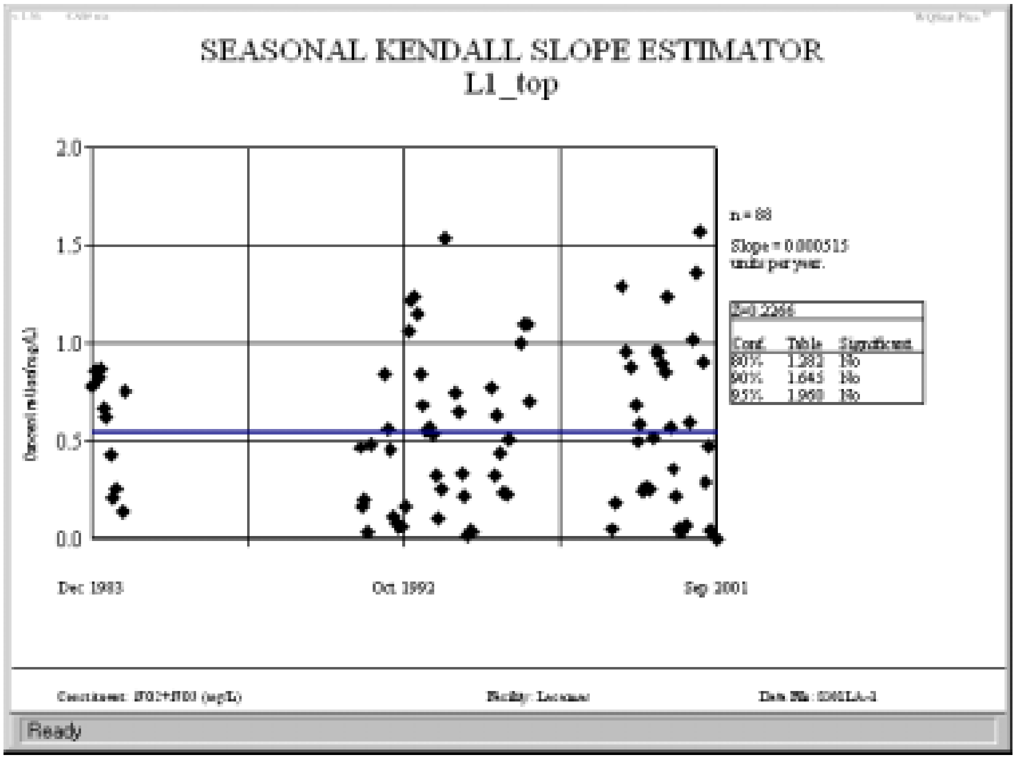


Figure 12. Annual box-and-whisker plots, Site L1 surface, nitrite+nitrate, 1984-2001.



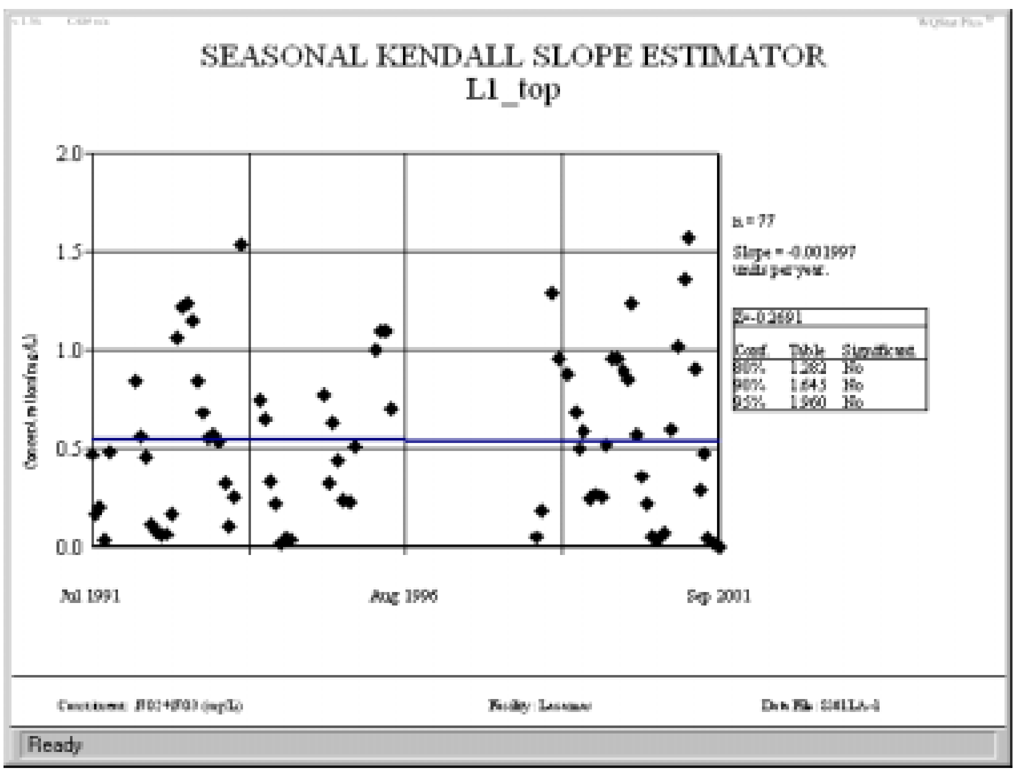


Figure 13. Seasonal Kendall test for trend, Site L1 surface, nitrate, 1984-2001 and 1991-2001.

3.3.8 Ammonia- Epilimnion

Ammonia concentration in the epilimnion remained below the reporting limit of 0.05 mg/L throughout most of WY 2000 and WY 2001, with peak values of 0.130 mg/L and 0.101 mg/L recorded in November 1999 and December 2000, respectively.

Since 1984, a slight downward trend (-0.002 mg/L/yr) in ammonia concentration is indicated at the 95% significance level (Figure 14) Since 1991, no trend is indicated.

3.3.9 Total Kjeldahl Nitrogen- Epilimnion

Epilimnetic TKN concentration was below the laboratory reporting limit of 1.0 mg/L during October and November 1999. Beginning in January 2000, laboratory procedures were adjusted to achieve a lower reporting limit. During the remainder of WY 2000, TKN values ranged from below the adjusted detection limit (<0.5 mg/L) during March 2000 to a peak of 1.15 mg/L during December 1999. During WY 2001, TKN ranged from 0.518 mg/L in May to 0.739 mg/L in December.

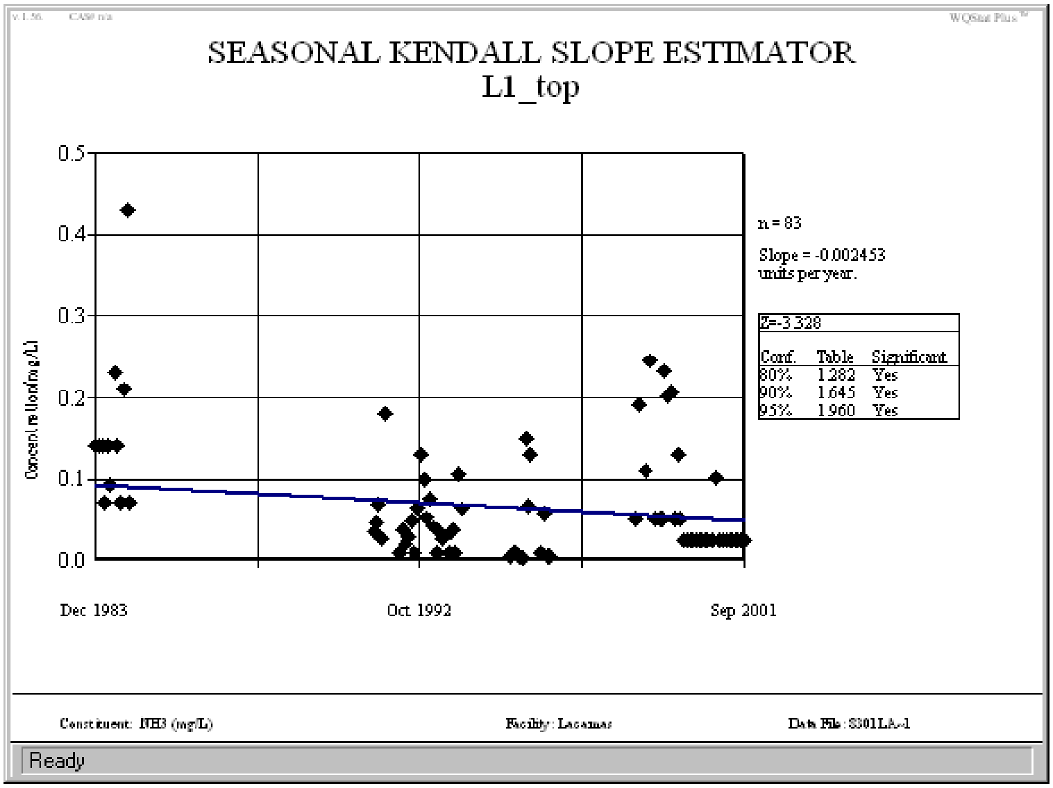
Annual box-and-whisker plots show similar variability in values since 1984, though the range of values appears to vary somewhat with annual climatic conditions (Figure 15). Trend tests indicate increasing epilimnetic TKN concentration at the 95% confidence level for both the 1984-2001 (+0.012 mg/L/yr) and 1991-2001 (+0.021 mg/L/yr) time periods (Figure 16).

3.3.10 Hypolimnetic Conditions

Conditions in the hypolimnion during WY 2000 and WY 2001 were very similar to observed patterns since 1984. Dissolved oxygen depletion was characteristically severe, as noted in section 3.2.2.

Annual box-and-whisker plots for the hypolimnion are contained in Appendix 8.

WY 2000 hypolimnetic total phosphorus concentration ranged from 0.018 mg/L during January 2000 to 0.187 mg/L in October 1999. Similarly, during WY 2001 TP concentration ranged from 0.008 mg/L during December 2000 to 0.143 mg/L in September 2001. In general, hypolimnetic TP concentration remained relatively low through the winter and early spring, increased gradually through summer, and rose dramatically during late summer and early fall. Hypolimnetic OP followed essentially the same annual pattern. During WY 2000, OP comprised a very large percentage of the TP through the winter months and a small percentage in the summer months. In WY 2001, OP comprised a large percentage of the TP throughout most of the year.



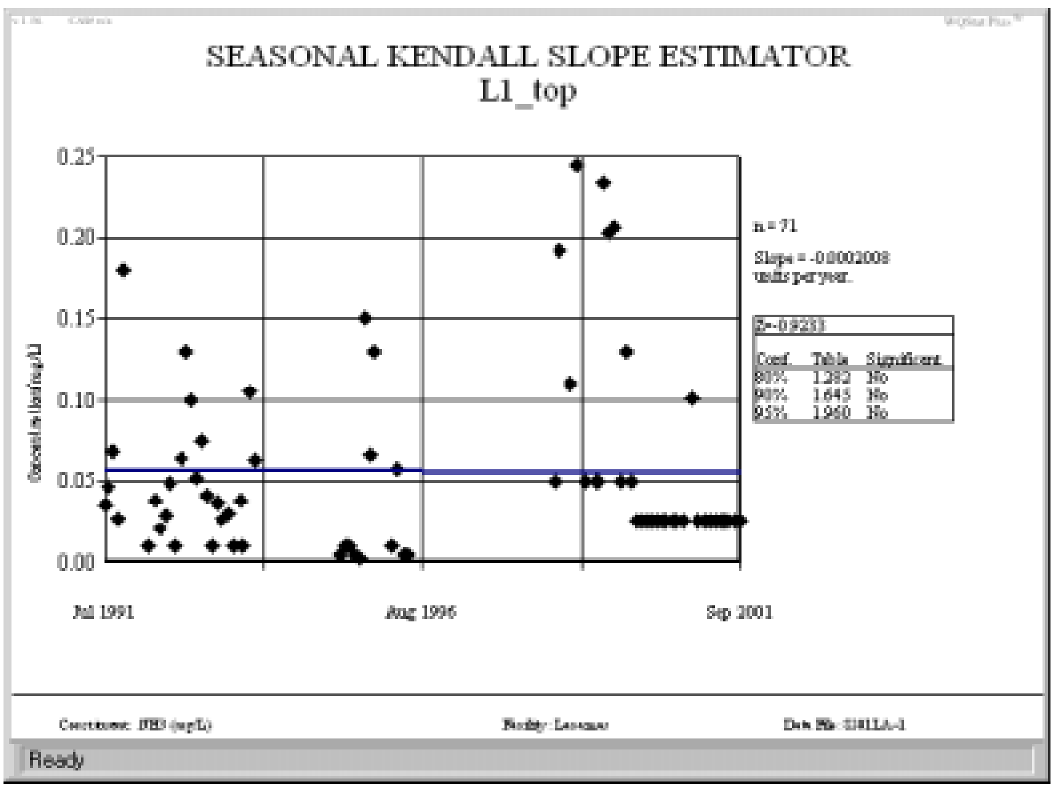


Figure 14 Seasonal Kendall test for trend, Site L1 surface, ammonia, 1984-2001 and 1991-2001.

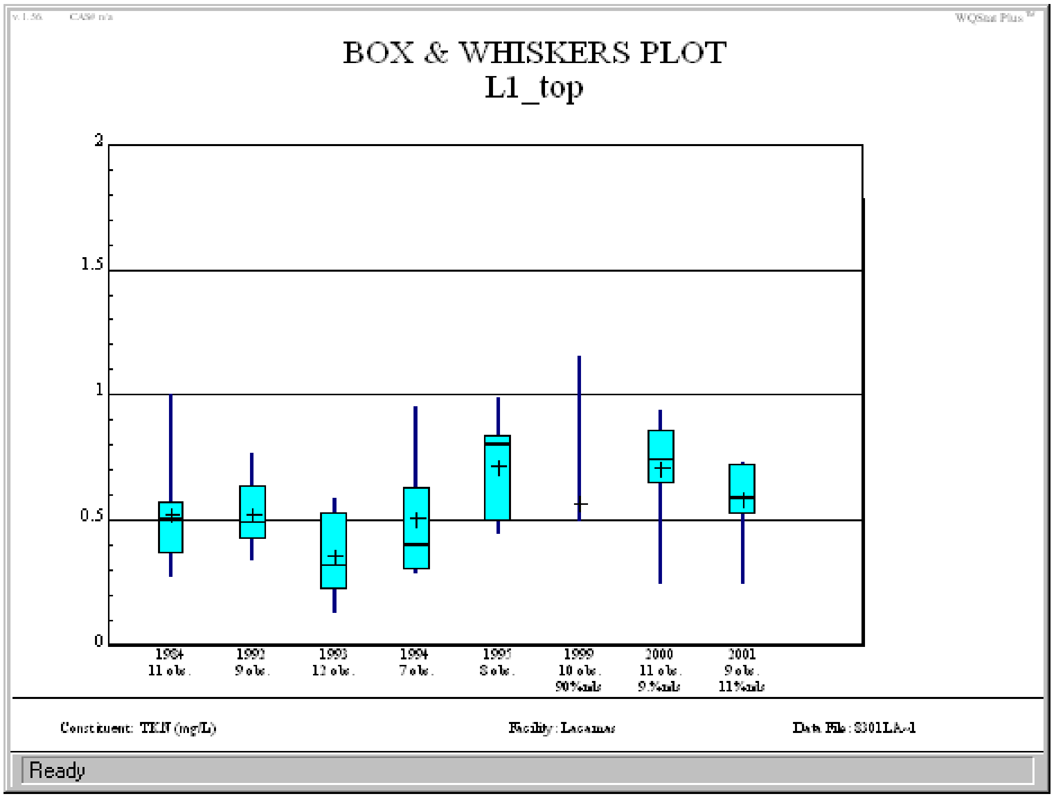
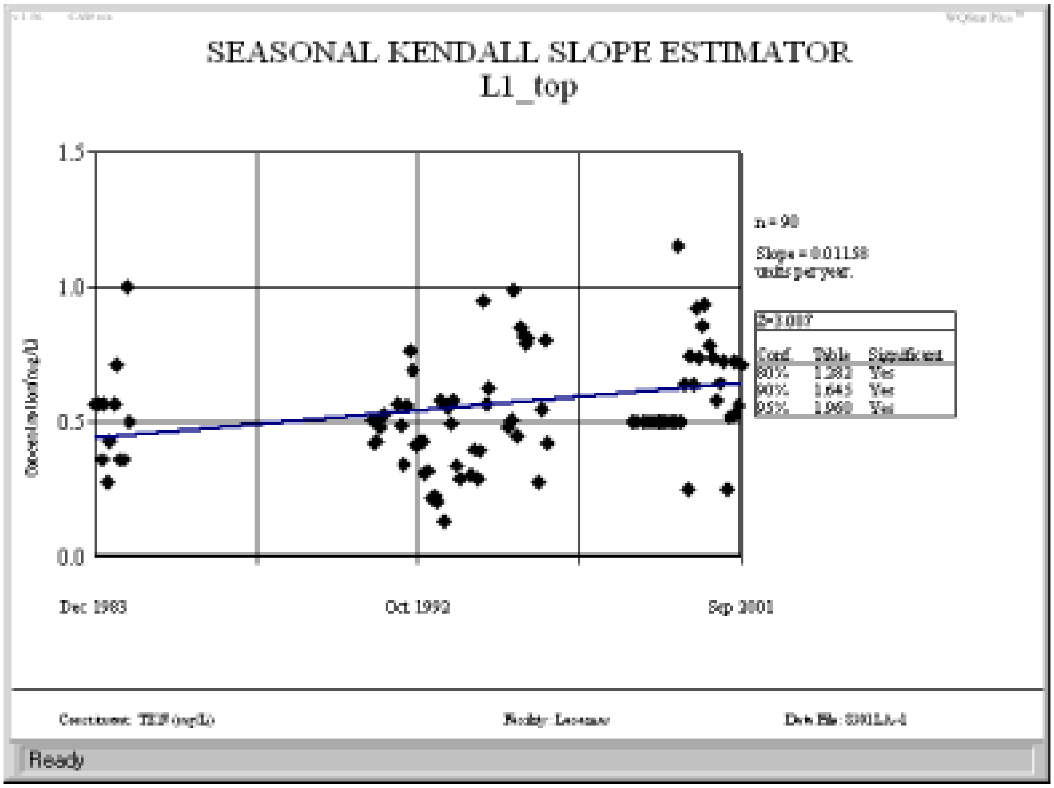


Figure 15. Annual box-and-whisker plots, Site L1 surface, total kjeldahl nitrogen, 1984-2001.



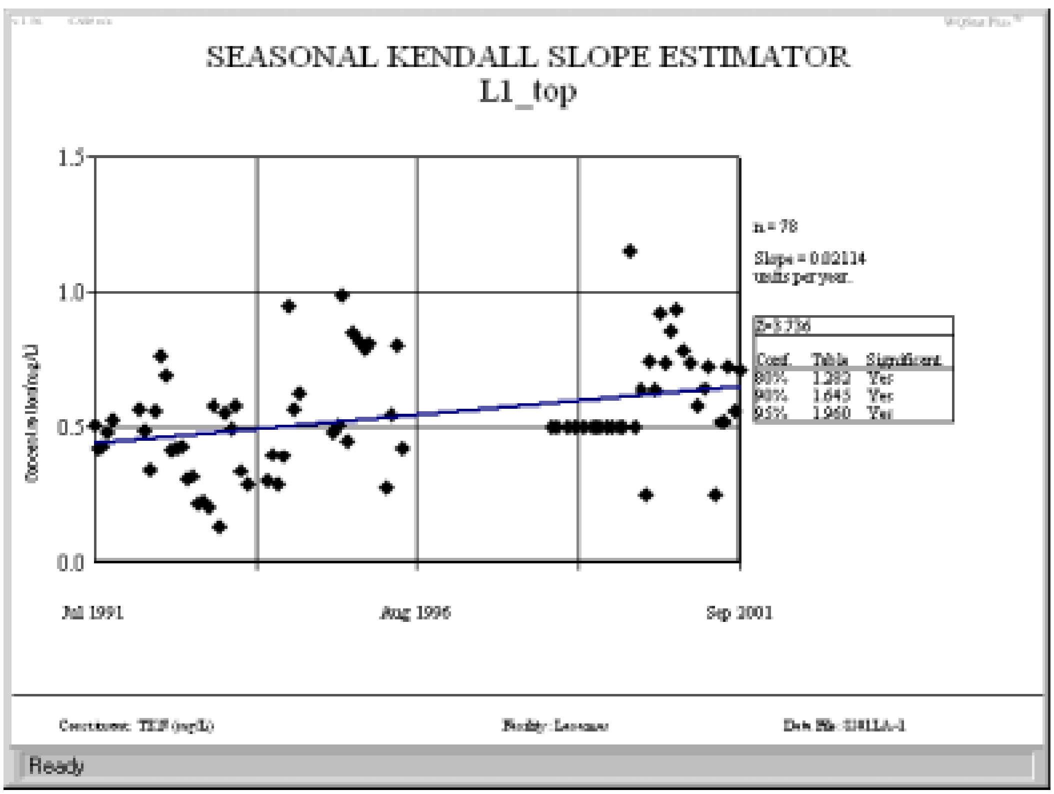


Figure 16 Seasonal Kendall test for trend, Site L1 surface, total kjeldahl nitrogen, 1984-2001 and 1991-2001.

3.4 Pollutant Loading Estimates

3.4.1 Total Annual Discharge/Loading

The annual hydrographs for WY 2000 and WY 2001 are located in Appendix 1. Following the hydrographs is an example page from a calculation spreadsheet used to estimate pollutant loads at Site A1.

Table 2 summarizes the annual total phosphorus and total suspended solids loading information for WY 2000 and WY 2001, as well as historical data from WY 1984 and WY 1999.

	~WY 1984	WY 1999	WY 2000	WY 2001
Total Stream Discharge (ac-ft/yr):	128,237	127,098	96,265	48,778
Mean Discharge (cfs)	n/a	176	133	67
TP Total In-load (kg):	14,387	7,560	6,414	3,061
TP load per volume (kg/ac-ft):	0.11	0.06	0.07	0.06
TP Total Out-load (kg):	12,161	n/a	5,065	1,785
% Retained:	15	n/a	21	42
Mean In-flow TP (mg/L)*:	0.089	0.050	0.061	0.046
Mean Out-flow TP (mg/L):	n/a	n/a	0.039	0.034
TSS Total In-load (kg):	1,820,000	812,094	1,238,691	719,246
TSS load per volume (kg/ac-ft):	14.2	6.4	12.9	14.8
TSS Total Out-load (kg):	n/a	n/a	543,242	464,888
% Retained:	n/a	n/a	56	35
Mean In-flow TSS (mg/L):	11.5	6.3	12.5	9.6
Mean Out-flow TSS (mg/L):	n/a	n/a	6.2	8.4

*EPA criteria for streams flowing into lakes is 0.050 mg/L

Table 2. Annual discharge with phosphorus and suspended solids loading summary, Lacamas Creek Site A1, 1984-2001.

3.4.2 Effect of Large Storms

The two largest peak-flow events of WY 2000 were during storm periods from November 24, 1999-December 1, 1999 and from December 16, 1999- December 23, 1999. Combined loads from these two periods were estimated to be 1436 kg of phosphorus and 172,769 kg of suspended solids. Stream discharge for the two storm periods combined was 14,458 acre-feet.

Figure 17 shows the relative effect of these two largest flow events as a percentage of annual totals. The 16-day period encompassed by the two events represents approximately 4% of the days in the water year. During that period, approximately 15% of annual discharge, 22% of annual phosphorus loading, and 14% of annual suspended solids loading occurred.

No similarly large flow events occurred during WY 2001.

Figure 18 shows three example storm events during which samples were collected at Site A1 and Site L0 to compare total phosphorus dynamics through the lake during runoff events. The storm events depicted occurred on Nov 22-Dec 3 1999, Jan 7-Jan 18 2000, and Jan 29-Feb 5 2000, respectively. Stage data are from Site A1. No stage data are available from Site LO. The use of Site A1 flow data to represent Site L0 is subject to some constraints, as discussed in section 2.4.2.

The relationship between in-flow and out-flow concentrations varied considerably through the three storm events. During the first storm, TP concentrations increased with streamflow at Site A1, and a net retention of TP in the lake was observed. In subsequent storms, a dilution effect was evident as TP concentrations decreased with increasing streamflow. During these storms, a net export of TP from the lake was observed.

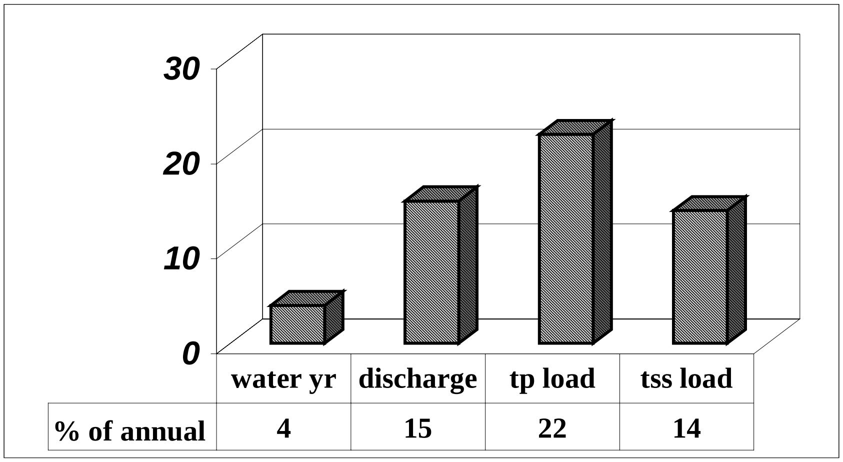


Figure 17. Percentage of WY 2000 annual loading totals represented by the two largest flow events (Nov 24-Dec 1, 1999 and Dec 16- Dec 22, 1999).

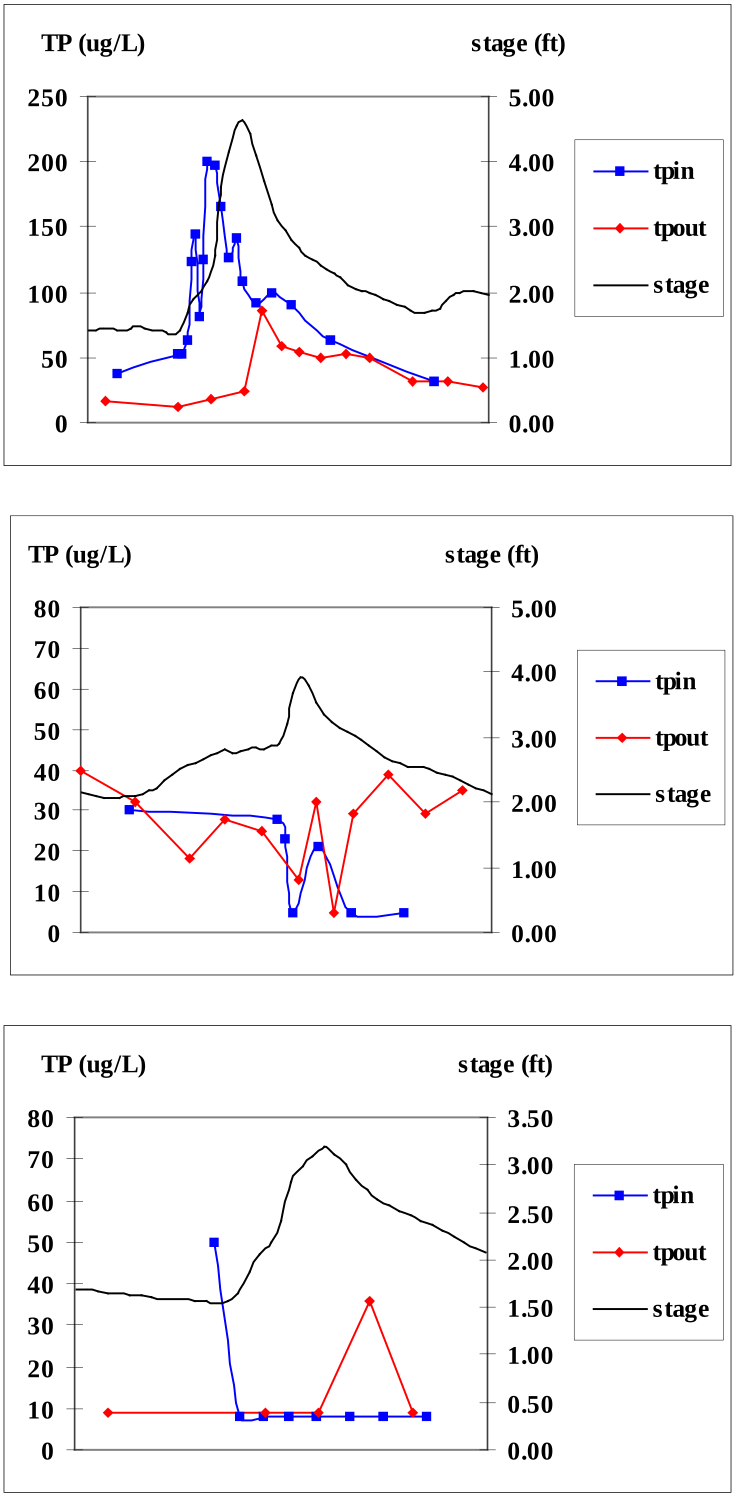


Figure 18. Comparison of total phosphorus concentrations at Site A1 (tpin) and Site L0 (tpout) through three storm events (Nov 22-Dec 3, 1999, Jan 7-Jan 18, 2000, and Jan 29-Feb 5, 2000 respectively).

4.0 Discussion

Discussion points below are not intended as a comprehensive summary of all aspects of Lacamas Lake monitoring over the course of the grant program. Numerous previous documents include detailed results and summaries which will not be reiterated here except where relevant to the immediate discussion. For complete information on other specific investigations carried out during the Lacamas Lake Restoration Program, refer to the reports listed in the References section.

4.1 Current conditions

The major trophic state indicators point to continued eutrophic conditions in Lacamas Lake. Mean epilimnetic TP concentration has decreased considerably from the ~0.070 mg/L levels reported in the early 1980s, but the current concentrations (around 0.030 mg/L) remain above the EPA criterion for eutrophication in lakes (0.025 mg/L). Mean Secchi disk readings have ranged from 1.3m to 1.5m in the past three years, meeting EPAs criterion for eutrophic conditions (<2.0m), and have not improved since 1984 when the mean secchi depth was 1.3m.

Lake TKN concentrations have increased, while seasonal patterns and ranges for most other water quality constituents, including TSS, NH_3, NO_3, and conductivity remain similar to those seen in the mid-1980s.

Algal productivity, though not measured directly in recent years, appears to remain high. At the time of the most recent phytoplankton investigation in 1995, the phytoplankton community was still dominated by eutrophic species such as *Fragilaria crotenensis,* and late summer blue-green algal blooms were occurring regularly. Aquatic macrophytes are consistently prolific, with nearly all available substrate colonized.

Summertime hypolimnetic dissolved oxygen depletion is severe. Anoxic conditions persist below the thermocline from April through September, with oxygen levels near zero below ~4m during much of this period. Epilimnetic dissolved oxygen concentrations appear to remain high enough to eliminate concern over summer fish kills. However, fish are forced into a narrow band of warm water near the surface of the lake during much of the year, and cold-water habitat is virtually non-existent from April through September. The State of Washington Fish and Wildlife Department suspects that stress and lack of habitat caused by hypolimnetic oxygen depletion are the primary limiting factors for both the cold-water and warm-water fisheries in Lacamas Lake (Mueler and Downen, 1999).

Annual TP loading to Lacamas Lake, though highly dependent on hydrologic conditions from year to year, has consistently hovered near 0.06 kilogram per acre-ft of discharge over the past three years, compared to approximately 0.11 kilogram per acre-ft in 1984. The annual mean concentration in Lacamas Creek has ranged from .046 to .061 mg/L, compared to a mean of 0.089 mg/L in 1984. The EPA criterion for creeks entering lakes is an annual mean concentration of 0.050 mg/L.

Like TP, annual TSS loading to Lacamas Lake also depends on annual hydrology, but TSS has not exhibited an overall decrease on a kg/acre-ft basis since 1984. Suspended solids loading to the lake remains high in wet years and slightly lower in dry years, with much of the heavier material probably being deposited toward the upper end of the lake.

Large rain events in late fall and early winter contribute a disproportionate share of the total annual load of phosphorus and suspended sediment to Lacamas Lake. However, summer baseflow in Lacamas Creek tends to have a higher total phosphorus concentration than winter baseflow.

A significant proportion of the annual total phosphorus and suspended solids loads remain in the lake. During the 2-3 years for which out-load data exists, an average of 26% of the TP and 46% of the TSS loads to the lake were retained. Though the retention rates vary considerably both seasonally and annually, it is clear that a large amount of material is deposited in the lake each year. Phosphorus retained in the lake may be recycled through the lake ecosystem, increasing the expected restoration time-frame well beyond the point when watershed loading is brought under control. TSS retained in the lake tends to create bars and expand shallow areas, which are subsequently populated by macrophytes.

4.2 Trends and Observations

Weather

The timing, intensity, and amount of rainfall has a significant impact on annual water quality in Lacamas Creek and Lacamas Lake. Hydrologic variation can lead to the mistaken impression that overall water quality conditions have changed, when in fact the observed change is driven primarily by differences in annual hydrology. This necessitates the collection of data over an extended time frame in order to filter out changes in water quality caused by seasonal and annual weather variation. The Lacamas watershed database has become extensive enough that we may begin to see trends appearing despite these fluctuations.

The overall climatic trends and patterns since 1976 have been: a) an increase in temperatures, and b) a cyclical pattern of wet and dry years. The long-term trends in lake water quality discussed in this report (1984-2001) encompass data collected in both wet and dry years and any detected trends take into account these fluctuations. Data for loading calculations have been collected only in WY 1984, WY 1999, WY 2000, and WY 2001. Of these years, 1984 and 1999 were very similar hydrologically, but 2000 and 2001 were considerably drier years. It should be noted that during drier years we can expect to see a decrease in total pollutant loading to the lake regardless of whether or not watershed management and restoration activities are having a positive impact, simply due to decreased transport of potentially polluting materials in runoff.

Lake and Stream

The mean concentration of TP in Lacamas Lake appears to have decreased significantly, and since 1984 exhibits an encouraging downward trend. Over the past three years, the mean epilimnetic concentration has hovered near the EPA criteria for lakes. Though still in the eutrophic range, this represents a vast improvement over the early 1980s. However, since 1991 no trend is apparent, suggesting that for the past decade the initial improvements in lake phosphorus concentration have merely held their own, rather than continuing to improve.

Dissolved oxygen conditions in the hypolimnion have not improved despite the apparent decrease in phosphorus concentration. This indicates that the oxygen depletion rate and overall primary productivity are still sufficiently high to cause anoxic conditions. On the positive side, summertime epilimnetic oxygen concentrations also appear to be decreasing slightly. This may indicate some improvement: decreasing oxygen production and less “super-saturation” of oxygen during summer daylight hours may signify a decrease in algal production.

However, the bottom line is that a decrease in phosphorus has not resulted in a concurrent increase in hypolimnetic dissolved oxygen. It is possible that by further reducing the phosphorus concentration to below the eutrophic threshold, dissolved oxygen in the hypolimnion would recover, but there is no indication that phosphorus levels are likely to decrease further without a major new implementation effort.

Phosphorus and suspended sediment loading to the lake is extremely dynamic. Storm events occurring only a few weeks apart result in quite different in-loading and out-loading scenarios. Early season storms appeared to cause spikes in Lacamas Creek TP concentration, and a substantial net retention of TP in the lake. Conversely, similar storms occurring a month or two later during the same winter resulted in dilution of TP concentrations in the creek and a net export of TP from Lacamas Lake. These findings highlight the importance of antecedent watershed conditions in determining the impacts from a given storm event. First-flush events are significant. Early season storms, storms occurring after a lengthy dry period, and unexpected storms occurring when development activities are unprepared for high levels of runoff are most likely to yield heavy pollutant loads.

Total phosphorus loading estimates over the past three years have been considerably lower than estimated loading in 1984, and mean concentrations have been much closer to the EPA criteria. Despite this overall improvement since 1984, over the past three years the amount of phosphorus loading per unit of stream volume has not decreased, and remains sufficiently high to cause eutrophication in Lacamas Lake.

It is possible that this observed halt in downward phosphorus trend is due to land-use changes in the watershed. The primary potential sources of phosphorus in the Lacamas watershed are animal waste and disturbed soils. The majority of necessary large-farm BMP projects were completed during the late 1980s and early 1990s, greatly diminishing large-scale agricultural phosphorus pollution. Further improvements stemming from BMP installation at smaller farms are not likely to be as dramatic, unless a very large percentage of landowners were to participate. Additionally, accelerated clearing and land-use conversion to residential and industrial uses, as well as golf courses, may be counteracting the improvements initially seen in the agricultural community.

During the summer, orthophosphorus concentrations in the lake are characteristically low as algae and macrophytes uptake this form of phosphorus very rapidly. However, an increasing trend in orthophosphorus is apparent since 1991. During winter, the majority of the phosphorus entering the lake appears to be in the orthophosphorus form, either as dissolved solids or attached to colloidal clay particles.

The TKN concentration in Lacamas Lake appears to be increasing since the early 1980s. This increasing trend in nitrogen is one of the most pronounced of the trends detected. Nitrogen is far more mobile than phosphorus, and the primary potential sources of nitrogen are animal waste, fertilizers, and septic tanks. The declining presence of commercial agriculture in the watershed does not suggest a high likelihood of increasing agricultural nitrogen sources. However, livestock on small "hobby" farms and increased fertilizer use by new homes, businesses, and golf courses are likely sources of the observed increase in TKN.

4.3 Special studies

4.3.1 Phosphorus release and dynamics

Determining the existence and extent of phosphorus releases from Lacamas Lake sediments has been an ongoing question since the program's inception. Phosphorus budgets, in-lake monitoring, and lake models performed early in the program gave conflicting indications. Laboratory experiments were conducted by E&S Environmental Chemistry, Inc, in the mid-1990s to further address the issue. Though the experiments were inconclusive, the results suggested that large releases of phosphorus from the sediments were probably not occurring in Lacamas Lake. In the event that releases *were* occurring, E&S concluded that the newly released phosphorus (P) would be trapped in the hypolimnion until fall turnover, at which time high winter flows would flush the P out of the lake. Therefore, any P released from the sediment would not contribute to algal blooms.

Current monitoring suggests that sediment release may in fact be occurring, but also supports the contention that the released P is unlikely to contribute to algal blooms. Water column TP values have remained relatively low throughout the lake until late summer or early fall, at which time a large spike occurs in the hypolimnion. Given the consistently low hypolimnetic values through the summer, it is likely that the dramatic increase in late summer is due, in part, to sediment release of phosphorus. Plant senescence and decay of algal material may also contribute.

Recent literature claims that wind-mixing and phosphorus concentration gradient are the two primary mechanisms for entrainment of hypolimnetic phosphorus into the epilimnion (Welch and Cooke, 1995). If entrainment occurs, then high levels of phosphorus in the hypolimnion may contribute to excess algae at the surface.

The Osgood index (the ratio of mean depth (m) to the square root of surface area (km2)) gives an indication of a lake's susceptibility to wind-mixing, because mixing depth increases as the square root of the area (Osgood 1988). An Osgood index of <4.0 can be an initial indicator that a lake may be prone to hypolimnetic P entrainment through wind mixing. The Osgood index for Lacamas Lake is 6.5, indicating that entrainment through wind-mixing is unlikely.

Further, the phosphorus concentration gradient in Lacamas Lake is quite low compared to lakes where gradients are responsible for significant P entrainment. The gradient in Lacamas Lake is not likely to result in large-scale transport of P into the epilimnion, and in any case the spikes in hypolimnetic P concentration seem to occur late in summer, when algal productivity is already in decline.

Based on the investigations performed during the Lacamas project, the weight of the evidence suggests that sediment phosphorus release due to anoxia in the hypolimnion is not a significant source of P for algal growth.

It should be noted, however, that the E&S experiments showed that sediment in Lacamas Lake does contain large amounts of phosphorus, and that re-suspension of the sediment can result in high water column P concentrations. Therefore, re-suspension of sediments through wave action or disturbance by watercraft (props or waves) in shallow areas has the potential to re-introduce large amounts of sedimented P into the water column.

4.3.2 Development Runoff Impacts

Development of golf courses and residential neighborhoods in close proximity to Lacamas and Round Lakes has presented several opportunities to monitor runoff entering the lakes from these sources during rain events. Data from these samples are on file with Clark County.

Samples were collected from a Goodwin Road ditch receiving runoff from Green Mountain Golf Course during the winter of 1998-1999 when construction was underway and large areas of soil were disturbed. These samples showed elevated TP concentrations at the point where the ditch enters Lacamas Creek (between 0.300 and 0.700 mg/L—recall that the EPA criterion for streams is 0.100 mg/L, and the EPA criterion for streams entering a lake is 0.050 mg/L). Subsequent inspections by Clark County Community Development determined that the developer was in compliance with County ordinances and BMP regulations. TP concentrations in the ditch remained high during rain events until golf course soils were seeded and stabilized, at which time ditch concentrations decreased to levels similar to Lacamas Creek background concentrations.

Samples were also collected from a small, unnamed tributary stream where it crosses Leonard Road immediately north of Round Lake. Residential development activities approximately 1/8 mile north of Leonard Road contributed sediment to the stream and lake during 1998 and 1999, substantially enlarging an existing delta in Round Lake. In November of 1998, a sample collected from the stream was measured at 0.675 mg/L TP and 343 mg/L TSS. Background concentrations in Round Lake were 0.056 mg/L TP and <10 mg/L TSS.

Repeated inspections by Clark County Community Development resulted in several small fines (~$250/each) and modifications to the BMPs at the development site. Subsequent to the BMP improvements (which included spreading straw on exposed soils and modifying the stormwater pond outflow gate), TP and TSS concentrations in the tributary returned to levels close to background Round Lake concentrations.

These examples illustrate the vital importance of effective erosion control and runoff control BMPs in developing areas. TP and TSS concentrations of the magnitude seen in these cases can have an enormous impact on downstream water quality even if the total discharge of polluted water is relatively small.

4.4 Current conditions vs. Program expectations

At the time the Lacamas program was initiated, the science of lake restoration was much less advanced. Expectations ran high, but the complexity and enormity of the restoration task was not always fully acknowledged. Although the authors of the Lacamas Restoration Plan in 1988 doubtless expected that their goals would be achieved in full, the current state of knowledge suggests that not every goal was realistic within the scope and context of the LLRP.

Achieving the goal of lake restoration is a complex and time-consuming process. It should be reiterated that on a nation-wide scale, improvements in lake water quality are rarely achieved in less than two or three decades through watershed management activities alone. Even when watershed sources of pollution are effectively curbed, it is common for lakes to require decades of additional time and in-lake management to recover from the impacts of years of degradation.

The authors of the Lacamas-Round Lake Diagnostic and Restoration Analysis (1985) utilized a widely applied model developed by Vollenweider (1976) to predict future lake conditions and to set phosphorus control goals for the Lacamas restoration effort. Despite the limitations noted above, it is still a useful exercise to compare the current status of Lacamas Lake to this historical goal in order to get a sense of how much progress has been made.

Vollenweider's model examines the relationship between phosphorus loading and trophic state as a function of mean depth and hydraulic retention time, which enables researchers to estimate the loading thresholds between trophic states. When combined with error analysis (Chapra and Reckhow, 1979), the Vollenweider model indicated that in order to achieve a 90% level of certainty that Lacamas Lake would change to a lower trophic state (mesotrophic), phosphorus loading would need to be decreased by 84%. The authors also predicted that this 84% reduction in phosphorus loading would only result in a 66% chance that the hypolimnion of Lacamas Lake would remain oxygenated during summer. Based on the model, an 84% reduction in phosphorus was adopted as a goal of the Lacamas Restoration Plan in 1988.

The information gathered to date suggests that annual phosphorus loading to Lacamas Lake has decreased by approximately half when compared to 1984. Although significant, this observed one-half reduction in phosphorus loading would clearly result in considerably less chance of improvement.

Given the Vollenweider model projections, it is not surprising that despite a substantial decrease in phosphorus loading, changes in trophic state and hypolimnetic oxygen have not yet been observed in Lacamas Lake. However, that is not to say efforts to control phosphorus loading have been wasted. Results of the 1998 E&S model and program review suggest that these efforts have likely prevented Lacamas Lake from deteriorating further, despite shifting land-use patterns and increasing human impacts in the watershed.

The admirable goal of 84% phosphorus reduction made the assumption that full BMP implementation could occur on 122 high-priority farms, and that the program would install several large wetland biofilters to remove additional phosphorus. Though the Lacamas Lake Restoration Program was able to cooperate successfully with 43 farms, numerous landowners declined to participate in the voluntary program.

Biofilters were not created due to engineering constraints in the lower watershed and a lack of support from the local Drainage Improvement District in the China Ditch subwatershed. Land-use changes in the watershed also rendered program goals difficult to achieve. While the restoration program was primarily focused on agricultural pollution, increasing impacts from residential and commercial development have become a significant new water quality issue.

4.5 Findings and Observations

Major findings and observations from the WY 2000-WY 2001 monitoring period and 1983-2001 trend testing include:

- Phosphorus loading and concentrations have been reduced substantially, though not drastically enough to bring about a shift in lake trophic state.
- Secchi disk transparency, phosphorus concentration, algae community structure, and hypolimnetic oxygen depletion all indicate that Lacamas Lake remains eutrophic.
- Summertime hypolimnetic dissolved oxygen depletion is severe and has not improved since 1983.
- Current monitoring supports the claim by State of Washington Fish and Wildlife (1997) that hypolimnetic oxygen depletion is the primary limiting factor for the Lacamas Lake fishery.
- Total Kjeldahl nitrogen has increased steadily in Lacamas Lake since 1983.
- Large storms during late fall and early winter account for a disproportionate share of annual total phosphorus and suspended solids loading to Lacamas Lake.
- Phosphorus concentrations in Lacamas Creek tend to be substantially higher during summer baseflow than during winter baseflow.
- Development activities in the Lacamas watershed can and do have a significant impact on lake and stream water quality.
- A significant portion of the phosphorus and suspended solids load to Lacamas Lake is retained in the lake and may further lengthen the time-frame needed for lake restoration.
- Phosphorus is probably released from Lacamas Lake sediments during late summer. However, it is unlikely that this phosphorus is contributing to excess algae growth.

4.6 Future Monitoring Recommendations

Some level of continued monitoring is recommended to document and track long-term conditions in the lake and creek. Future monitoring plans should be designed with the goal of detecting significant long-term changes in pollutant loading, water quality, or biota, such that appropriate modifications can be made to lake and watershed management strategies.

In addition, the following questions may deserve further attention for lake management:

1) Have changes in water chemistry (specifically nitrogen and phosphorus concentrations) led to any change in population dynamics or decrease in overall productivity of the algal community?

   The phytoplankton community has not been monitored since 1995. Given changes in nutrient concentrations in the lake and a decline in surface oxygen supersaturation during recent summers, it is possible that primary productivity has declined. Also, it is unknown whether the phytoplankton community is still dominated by species associated with eutrophication.

2) How important is the role of nitrogen in the eutrophication of Lacamas Lake?

   E&S Environmental Chemistry, Inc., has noted that the role of nitrogen in lake eutrophication has received greater attention in recent years (1998). The effects of the increased nitrogen load or modified phosphorus:nitrogen ratios on water quality and biota in Lacamas Lake are largely unknown. Information on nitrogen sources in the watershed is also incomplete.

3) How does motorized watercraft use in shallow areas of Lacamas Lake impact sediment and phosphorus re-suspension?

   E&S experiments have shown that Lacamas Lake sediments contain large amounts of phosphorus, and that this phosphorus may be re-suspended in the water column when the sediment is agitated. Lacamas Lake experiences heavy use by motorized watercraft, and much of this use occurs in shallow water areas. Additionally, the City of Camas plans to install a public boat launch in the shallow narrows near the south-east end of Lacamas Lake. Appropriate study and cooperative dialogue between Camas and Clark County could help to insure that increased boat traffic in this shallow area does not result in increased sediment disturbance or phosphorus pollution.

4.7 Conclusion

Current monitoring results and trend analyses support the premise put forth by E&S (1998), that future Lacamas Lake management efforts should focus not on returning the lake to a pristine state but rather on maintaining and enhancing current beneficial uses and minimizing further degradation.

The Lacamas watershed has been and will continue to be impacted by human activities. Despite significant progress in controlling phosphorus pollution, historical and ongoing land use changes have permanently altered the lake and watershed in ways that render a return to pristine, pre-settlement conditions infeasible. Lacamas Lake and its watershed will require diligent, ongoing management to protect and enhance current beneficial uses such as fishing, boating, and aesthetics, especially given increasing impacts from a growing population. Continued commitment and prudent management choices are needed if Lacamas Lake and its watershed are to remain valuable community assets for future generations.

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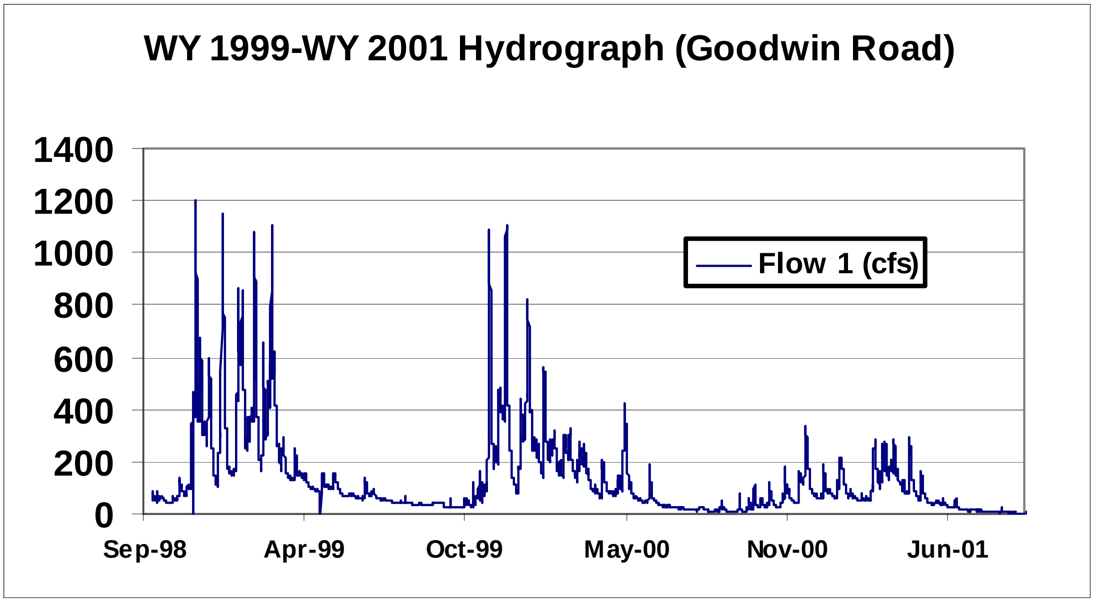
Appendices

Appendix 1: Lacamas Creek hydrograph, Site A1, WY 1999-WY 2001, and example loading calculation spreadsheet.



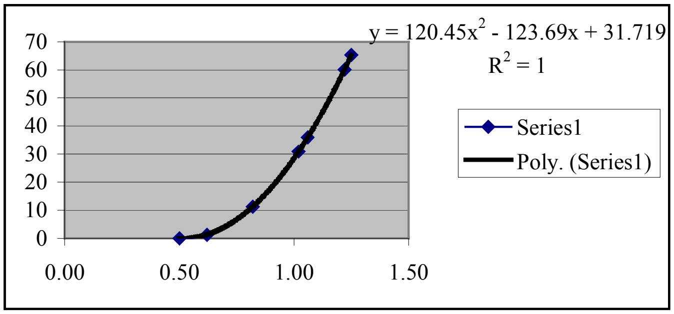
Example page from loading calculation spreadsheet, WY 2001, Lacamas Creek at Goodwin Rd:

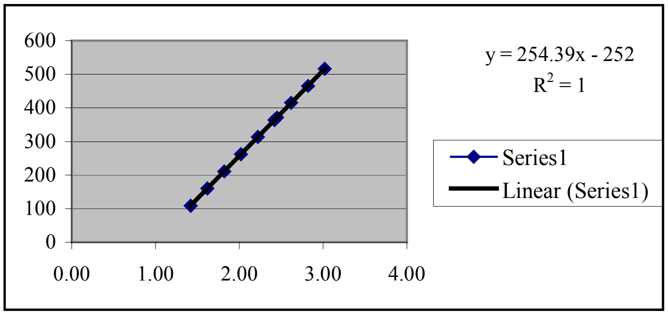
Date	Time	Flow 1 (cfs)	TP (mg/L)	TSS (mg/L)	Flow per interval (acre-ft)	Flow per interval (L)	TP Conc. (kg/L)	TSS Conc. (kg/L)	TP LOAD (kg)	TSS LOAD (kg)
30-Sep-01	12:00p.m.	7.4	0.052	3.0	0.61	755035	5.2E-08	0.000003	0.04	2.27
30-Sep-01	01:00p.m.	7.4	0.052	3.0	0.61	755035	5.2E-08	0.000003	0.04	2.27
30-Sep-01	02:00p.m.	7.3	0.052	3.0	0.61	748943	5.2E-08	0.000003	0.04	2.25
30-Sep-01	03:00p.m.	7.4	0.052	3.0	0.61	755035	5.2E-08	0.000003	0.04	2.27
30-Sep-01	04:00p.m.	7.4	0.052	3.0	0.61	755035	5.2E-08	0.000003	0.04	2.27
30-Sep-01	05:00p.m.	7.4	0.052	3.0	0.61	755035	5.2E-08	0.000003	0.04	2.27
30-Sep-01	06:00p.m.	7.3	0.052	3.0	0.61	748943	5.2E-08	0.000003	0.04	2.25
30-Sep-01	07:00p.m.	7.2	0.052	3.0	0.60	736832	5.2E-08	0.000003	0.04	2.21
30-Sep-01	08:00p.m.	7.3	0.052	3.0	0.60	742875	5.2E-08	0.000003	0.04	2.23
30-Sep-01	09:00p.m.	7.2	0.052	3.0	0.60	736832	5.2E-08	0.000003	0.04	2.21
30-Sep-01	10:00p.m.	7.0	0.052	3.0	0.58	712906	5.2E-08	0.000003	0.04	2.14
30-Sep-01	11:00p.m.	6.8	0.052	3.0	0.56	695219	5.2E-08	0.000003	0.04	2.09
	weighted	mean=	mean=	mean=						
		67.4	0.046	9.6	48778.45				3061	719246
		cfs	mg/L	mg/L	acre-feet				kg	kg

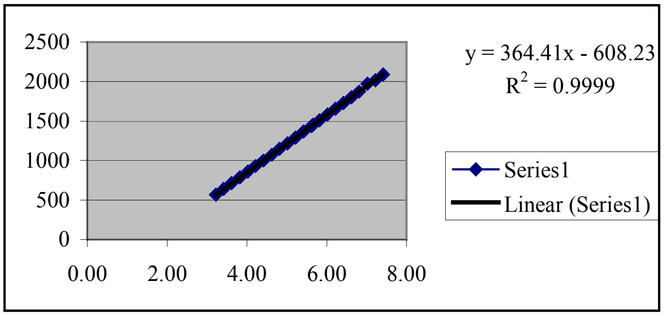
Appendix 2: Stage vs Discharge equations for Lacamas Creek at Goodwin Road, WY 2000 and WY 2001

Lacamas Creek at Goodwin Road
Stage vs Discharge Equations
Jan 1, 1999-Present
(adjusted +0.42' from Glen Dorsey gage)

Glen D Stage (ft)	**Sigma Adjusted Stage (ft)**	**Discharge (cfs)**
0.08	**0.50**	**0.0**
0.20	**0.62**	**1.3**
0.40	**0.82**	**11.3**
0.60	**1.02**	**30.9**
0.64	**1.06**	**35.9**
0.80	**1.22**	**60.1**
0.83	**1.25**	**65.3**
1.00	**1.42**	**109**
1.20	**1.62**	**160**
1.40	**1.82**	**211**
1.60	**2.02**	**262**
1.80	**2.22**	**313**
2.00	**2.42**	**364**
2.03	**2.45**	**371**
2.20	**2.62**	**415**
2.40	**2.82**	**465**
2.60	**3.02**	**516**
2.80	**3.22**	**567**
3.00	**3.42**	**639**
3.20	**3.62**	**712**
3.40	**3.82**	**785**
3.60	**4.02**	**857**
3.80	**4.22**	**930**
4.00	**4.42**	**1002**
4.20	**4.62**	**1075**
4.40	**4.82**	**1148**
4.60	**5.02**	**1220**
4.80	**5.22**	**1293**
5.00	**5.42**	**1366**
5.20	**5.62**	**1438**
5.24	**5.66**	**1453**
5.40	**5.82**	**1511**
5.60	**6.02**	**1583**
5.80	**6.22**	**1656**
6.00	**6.42**	**1729**
6.20	**6.62**	**1801**
6.40	**6.82**	**1874**
6.60	**7.02**	**1974**
6.80	**7.22**	**2019**
7.00	**7.42**	**2092**







Appendix 3: WY 2000 and WY 2001 Lacamas Lake data plus QA samples

Station	Parameter	22-Oct-99	10/22 dups	18-Nov-99	11/18 dups	22-Dec-99	12/22 dups	26-Jan-00	1/26 dups	28-Feb-00	2/28 dups
L1 top	**TSS**	ND		ND	5.000	ND		ND	ND	ND	
	NH3	ND	ND	0.130		ND	ND	ND		ND	ND
	TKN	ND	ND	ND		1.150	0.800	0.504		0.641	0.765
	OP	ND		0.019	0.019	0.024		0.014	0.014	0.013	
	TP	0.022	0.024	0.033		0.032	0.035	ND		0.053	0.054
	NO2+NO3	0.253		0.523	0.519	0.960		0.959	0.990	0.900	
L1 mid	**TSS**	ND		8.000		ND		ND	ND, ND	ND	6.000
	NH3	0.139		0.124		ND		ND		ND	
	TKN	ND		ND		0.900		ND		0.574	
	OP	0.003		0.034		0.025		0.014	.014, .014	0.011	0.010
	TP	0.025		0.049		0.028		ND		0.044	
	NO2+NO3	0.328		0.652		0.970		0.985	0.989, 1.02	0.915	0.941
L1 bot	**TSS**	12.000	10.000	5.000		ND	ND	ND		ND	
	NH3	0.900		0.197	0.376	ND		ND	ND	ND	
	TKN	1.180		ND	ND	0.880		ND	ND	0.517	
	OP	0.114	0.108	0.048		0.027	0.027	0.015		0.010	
	TP	0.187		0.068	0.053	0.029		0.018	ND	0.022	
	NO2+NO3	ND	ND	0.635		1.040	1.070	1.010		0.984	

Station	Parameter	23-Mar-00	3/23 dups	18-Apr-00	4/18 dups	16-May-00	5/16 dups	19-Jun-00	6/19 dups
L1 top	**TSS**	ND	ND	ND		ND	ND	10.000	
	NH3	ND		ND	ND	ND		ND	ND
	TKN	ND		0.745	0.760	0.640		0.924	0.977
	OP	0.008	0.007	0.006		ND	ND	ND	
	TP	0.024		0.033	0.032	0.024		0.043	0.041
	NO2+NO3	0.850	0.885	1.240		0.573	0.582	0.357	
L1 mid	**TSS**	ND		ND		ND		6.500	
	NH3	ND		ND		ND	ND	ND	
	TKN	ND		0.613		0.619	0.529	0.789	
	OP	0.008		0.006		0.014		ND	
	TP	0.019		0.023		0.040	0.029	0.035	
	NO2+NO3	0.775		0.865		0.768		0.600	
L1 bot	**TSS**	ND		ND	ND	ND		ND	ND
	NH3	0.127	0.138	0.103		ND		0.061	
	TKN	0.588	0.603	0.882		0.442		0.629	
	OP	0.009		0.012	0.012	0.009		0.006	0.006
	TP	0.033	0.030	0.037		0.047		0.048	
	NO2+NO3	0.740		0.850	1.030	0.891		0.573	0.592

Station	Parameter	15-Aug-00	8/15 dups	13-Sep-00	9/13 dups
L1 top	TSS	8.500	7.500	ND	
	NH3	ND		ND	ND
	TKN	0.855		0.934	1.070
	OP	ND	ND	0.024	
	TP	0.027		0.034	0.023
	NO2+NO3	0.051	0.049	0.040	
L1 mid	TSS	ND		ND	
	NH3	ND		0.052	
	TKN	0.700		0.560	
	OP	ND		ND	
	TP	0.032		0.018	
	NO2+NO3	0.408		0.286	
L1 bot	TSS	ND		ND	ND
	NH3	0.122	0.131	0.422	
	TKN	0.485	0.538	0.976	
	OP	ND		0.142	0.121
	TP	0.052	0.056	0.128	
	NO2+NO3	0.278		ND	0.058

Station	Parameter	23-Oct-00	10/23/01 dups	07-Dec-00	12/07/00 dups	16-Jan-01	01/16/01 dups	21-Feb-01	02/21/01 dups
		< RL							
L1 top	**TSS**	6.5	5.5	3.0		<5.0		<5.0	31.0
	NH3	<0.050		0.101	0.099	<0.050	<0.050	<0.050	
	TKN	0.785		0.739	<0.500	0.583	<0.500	0.643	
	OP	0.013	<0.010	0.008		0.019		0.020	0.013
	TP	0.039		0.029	0.035	0.033	0.020	0.023	
	NO2+NO3	0.112	0.029	0.600		1.020		1.360	1.080
L1 mid	**TSS**	30.0		2.6	3.4	<5.0		<5.0	
	NH3	<0.050		0.098		<0.050		<0.050	<0.050
	TKN	0.949		0.611		0.579		<0.500	<0.500
	OP	<0.010		0.008	0.009	0.018		0.014	
	TP	0.033		0.031		0.016		0.020	<0.010
	NO2+NO3	0.130		0.580	0.640	1.080		1.600	
L1 bot	**TSS**	8.0		3.8		<5.0	<5.0	<5.0	
	NH3	0.350	0.350	0.098		<0.050		<0.050	
	TKN	1.000	0.790	<0.500		0.565		<0.500	
	OP	<0.010		0.008		0.019	0.019	0.013	
	TP	0.055	0.055	0.033		0.022		0.022	
	NO2+NO3	0.024		0.590		1.030	1.110	1.260	

Station	Parameter	25-Apr-01	04/25/01 dups	24-May-01	05/24/01 dups*	20-Jun-01	06/20/01 dups	11-Jul-01	07/11/01 dups
L1 top	**TSS**	3.3	4.3	7.8	8.8	3.6		7.0	7.4
	NH3	<0.050		<0.050		<0.050	<0.050	<0.050	
	TKN	<0.500		0.518		0.787	<0.500	0.727	
	OP	0.018	0.015	<0.005	<0.005	0.010		0.006	0.006
	TP	0.025		0.024		0.026	0.017	0.019	
	NO2+NO3	0.902	0.045	0.288	0.247	0.478		0.027	0.058
L1 mid	**TSS**	4.0		7.4		3.6		5.9	
	NH3	<0.050		<0.050		<0.050		<0.050	
	TKN	<0.500		<0.500		0.578		0.736	
	OP	0.017		<0.005		0.014		0.008	
	TP	0.027		0.039		0.037		0.029	
	NO2+NO3	1.130		0.295		0.659		0.342	
L1 bot	**TSS**	4.0		2.2		<2.0	<2.0	<1.9	
	NH3	<0.050	<0.050	<0.050	0.050	0.099		0.141	0.190
	TKN	0.575	0.607	0.544	<0.500	0.732		0.620	0.549
	OP	0.028		0.008		0.020	0.02	0.008	
	TP	0.032	0.034	0.038	0.038	0.029		0.018	0.022
	NO2+NO3	1.700		0.491		0.661	0.687	0.537	

Station	Parameter	17-Sep-01	09/17/01 dups*
L1 top	TSS	4.3	
	NH3	<0.050	<0.050
	TKN	0.662	0.765
	OP	0.018	
	TP	0.039	0.043
	NO2+NO3	<0.005	
L1 mid	TSS	3.2	
	NH3	0.180	
	TKN	0.534	
	OP	0.024	
	TP	0.037	
	NO2+NO3	0.046	
L1 bot	TSS	5.7	4.3
	NH3	0.607	
	TKN	1.190	
	OP	0.125	0.126
	TP	0.143	
	NO2+NO3	0.010	0.011

Log File Name : 10/22/99
Setup Date (MMDDYY) : 102299
Setup Time (HHMMSS) : 113128

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
102299	113309	7.3	30.7	17.01	10.52	0.18	x	135.3
102299	113514	7.2	30.2	15.96	10.58	0.17	x	122.8
102299	113608	7.2	30.4	14.35	10.64	0.17	x	120.3
102299	113705	7.2	28.6	14.00	10.78	0.14	x	110.2
102299	113816	7.2	28.3	12.98	11.05	0.14	x	93.7
102299	113925	7.2	27.8	12.00	11.48	0.79	x	98.1
102299	114040	7.2	27.1	11.03	12.58	4.41	x	98.5
102299	114132	7.2	26.8	10.00	12.98	5.19	x	98.2
102299	114215	7.2	27.1	9.00	13.13	5.53	x	98
102299	114352	7.2	25.9	8.01	13.16	5.68	x	97.9
102299	114531	7.2	25.8	7.02	13.29	6.58	x	98.1
102299	114647	7.2	25.4	6.02	13.37	7.36	x	98.3
102299	114742	7.2	24.8	5.03	13.39	7.55	x	98.3
102299	114910	7.2	25.5	4.00	13.4	7.56	x	98.1
102299	115003	7.2	24.7	3.03	13.41	7.56	x	98.3
102299	115151	7.2	23.8	1.70	13.44	7.7	x	98.4
102299	115246	7.1	21.9	1.00	13.53	7.87	x	98.2
102299	115353	7.2	24.1	-0.14	13.88	7.64	x	0

Recovery finished at 020100 114309

Log File Name : 11/18/99
Setup Date (MMDDYY) : 111899
Setup Time (HHMMSS) : 100356

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
111899	112619	7.2	26.3	16.92	10.26	1.44	x	110.5
111899	112704	7.2	25.3	15.98	10.36	2.39	x	107.9
111899	112802	7.2	24.4	14.97	10.38	3.31	x	103.2
111899	112913	7.1	23.2	13.99	10.53	4.61	x	105.8
111899	113001	7.1	22.5	13.02	10.53	4.74	x	106.2
111899	113059	7.1	21.7	12.04	10.55	5.21	x	105.5
111899	113159	7.1	21.8	11.04	10.58	6	x	106
111899	113301	7.1	21	9.98	10.62	6.84	x	105.5
111899	113354	7.1	20.5	8.97	10.64	6.8	x	94.6
111899	113438	7.1	19.4	8.02	10.69	7.14	x	95.6
111899	113557	7.1	19.5	7	10.75	7.21	x	96.5
111899	113649	7.1	18.6	5.53	10.84	7.46	x	98.9
111899	113735	7.1	18.4	5.04	10.87	7.48	x	99.4
111899	113818	7.1	17.9	4	10.87	7.49	x	99.4
111899	113945	7.1	17.5	2.75	10.88	7.5	x	100.8
111899	114034	7.1	17.1	1.98	10.89	7.54	x	101.2
111899	114151	7.1	16.3	1	10.91	7.62	x	100.8
111899	114231	7.1	16.9	0.03	10.93	7.62	x	100.5

Log File Name : 12/22/99
Setup Date (MMDDYY) : 122299
Setup Time (HHMMSS) : 110216

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
122299	124320	7.7	59.8	15.6	7.49	9.16	x	48.5
122299	124427	7.7	59.6	14.05	7.52	9.14	x	48.3
122299	124542	7.7	59.3	13.34	7.54	9.17	x	48.1
122299	124628	7.6	59	12.02	7.71	9.12	x	47.4
122299	124834	7.7	57.9	11.03	7.94	9.13	x	46.8
122299	124930	7.6	58	10.22	8.04	9.12	x	47
122299	125010	7.6	57.3	8.86	8.06	9.15	x	47
122299	125103	7.6	57	8.38	8.08	9.14	x	47.1
122299	125130	7.6	56.6	7.03	8.08	9.14	x	47
122299	125211	7.6	57.1	6.05	8.15	9.1	x	46.6
122299	125305	7.6	56.6	4.78	8.22	9.1	x	46.4
122299	125537	7.6	56.1	3.77	8.26	9.32	x	46.2
122299	125616	7.6	56.7	1.84	8.29	9.23	x	46.2
122299	125723	7.6	55.4	1.85	8.26	9.16	x	46.2
122299	125754	7.6	56.2	1.12	8.29	9.14	x	46.1
122299	125838	7.6	55.2	0.09	8.27	9.21	x	46.6

Recovery finished at 020100 114439

Log File Name : 1/26/00
Setup Date (MMDDYY) : 012600
Setup Time (HHMMSS) : 110041

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
12600	124122	7.6	52.4	16.99	5.06	10.61	x	49.1
12600	124218	7.6	52.1	16.01	5.05	10.65	x	49.5
12600	124310	7.6	52.1	15.01	5.05	10.61	x	49.5
12600	124341	7.6	51.9	14.04	5.05	10.69	x	49.3
12600	124427	7.5	51.7	13.02	5.05	10.73	x	49.6
12600	124458	7.5	51.9	11.88	5.05	10.77	x	49.6
12600	124532	7.6	51.5	10.97	5.05	10.81	x	49.5
12600	124605	7.5	51.5	9.53	5.05	10.9	x	49.6
12600	124647	7.5	50.4	9.02	5.05	10.94	x	49.5
12600	124717	7.5	50.5	8.01	5.05	10.97	x	49.5
12600	124752	7.5	49.8	7.01	5.05	10.97	x	49.8
12600	124826	7.5	50	6.04	5.05	10.94	x	49.6
12600	124905	7.5	49.8	4.98	5.06	10.94	x	49.6
12600	124947	7.5	49.6	4.2	5.09	10.94	x	49.4
12600	125035	7.5	49.9	3.12	5.09	11.04	x	49.6
12600	125112	7.5	49.7	2.09	5.13	11.03	x	49.9
12600	125147	7.5	49.6	0.58	5.22	11.03	x	50.5
12600	125227	7.5	48.8	0.04	5.54	10.89	x	51.9

Log File Name : 2/28/00
Setup Date (MMDDYY) : 022800
Setup Time (HHMMSS) : 111846

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units
22800	125521	7.6	53.8	15.94	6.46	9.81	x
22800	125617	7.6	51.6	14.09	6.47	10.05	x
22800	125727	7.6	52	11.94	6.48	10.24	x
22800	125836	7.6	52	9.98	6.6	10.38	x
22800	125931	7.5	51.3	7.98	6.62	10.43	x
22800	130020	7.5	50.6	6.98	6.75	10.56	x
22800	130100	7.5	50.5	5.88	6.84	10.68	x
22800	130131	7.5	50.1	4.98	6.93	10.76	x
22800	130201	7.5	50.1	4.04	6.96	10.8	x
22800	130236	7.5	50.2	2.99	7.16	10.76	x
22800	130317	7.5	50.1	2	7.42	10.72	x
22800	130404	7.5	47.3	0.96	7.7	10.61	x
22800	130433	7.5	49	0.02	7.74	10.54	x

Recovery finished at 083000 130016

Log File Name : 3/23/00
Setup Date (MMDDYY) : 032400
Setup Time (HHMMSS) : 112359

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units
32400	133220	7.6	53.2	16.77	7.23	7.11	x
32400	133339	7.6	52.4	14.59	7.36	7.79	x
32400	133456	7.6	51	12.93	7.45	8.24	x
32400	133557	7.6	51.8	11.38	7.76	8.85	x
32400	133640	7.5	50.5	9.94	7.79	9	x
32400	133720	7.5	50.5	9.1	7.88	9.15	x
32400	133810	7.5	50	8.14	7.89	9.15	x
32400	133908	7.5	49.5	7.11	7.97	9.38	x
32400	133955	7.5	49.7	6.09	8.07	9.51	x
32400	134035	7.5	49.6	5.09	8.11	9.54	x
32400	134118	7.5	48.7	4.12	8.19	9.67	x
32400	134157	7.5	48.6	3.08	8.27	9.73	x
32400	134242	7.5	49.3	1.47	8.32	9.93	x
32400	134333	7.5	49.1	0.86	8.61	10.22	x
32400	134416	7.5	48.1	0.09	8.8	10.24	x

Log File Name : 04/18/00
Setup Date (MMDDYY) : 041900
Setup Time (HHMMSS) : 090644

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
41900	104321	7.6	53.3	16.89	7.73	4.3	x	6
41900	104448	7.6	52.2	15.02	7.72	6.08	x	6
41900	104645	7.5	48.9	13	7.86	7.75	x	6
41900	104755	7.5	51	10.96	8.02	7.66	x	
41900	104921	7.5	50	9.98	8.21	7.72	x	6
41900	105015	7.5	49.5	8.99	8.33	7.59	x	6
41900	105125	7.5	48.6	7.95	8.47	7.9	x	6
41900	105229	7.5	48.6	6.97	8.72	8.05	x	6
41900	105353	7.5	48.6	5.97	9.17	8.34	x	6
41900	105502	7.5	48.9	4.56	9.99	8.67	x	6
41900	105556	7.5	48.1	4	10.71	9.1	x	6
41900	105707	7.5	46.2	2.99	11.77	9.46	x	7
41900	105830	7.5	48.5	2.01	13.04	10.82	x	7
41900	105928	7.5	47.3	1.01	13.49	11.12	x	7
41900	110009	7.5	47.5	0.01	14.1	11.21	x	7

Recovery finished at 083000 132403

Log File Name : 5/16/00
Setup Date (MMDDYY) : 051700
Setup Time (HHMMSS) : 120111

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
51700	120416	7.5	46.8	17.01	8.04	3.9	x	6
51700	120525	7.5	46.8	15.98	8.03	3.31	x	6
51700	120614	7.5	46.2	15.02	8.05	3.24	x	6
51700	120711	7.5	46.8	13.94	8.1	3.08	x	6
51700	120754	7.5	46	12.63	8.38	3.63	x	6
51700	120839	7.5	44.3	12.02	8.86	4.32	x	6
51700	120924	7.5	45.9	11.04	9.08	4.73	x	6
51700	121016	7.5	45.5	10.09	9.3	5.09	x	6
51700	121055	7.5	45.9	9.02	9.43	5.42	x	6
51700	121130	7.5	45.6	8.01	9.61	5.64	x	
51700	121214	7.5	45.6	7.01	9.79	5.92	x	6
51700	121258	7.5	44.6	6.02	10.17	6.5	x	
51700	121347	7.5	44.7	5.01	10.54	6.82	x	6
51700	121449	7.5	45.1	3.95	11.1	7.36	x	6
51700	121529	7.5	44.6	3.03	11.96	7.48	x	5
51700	121616	7.5	44.5	2.05	13.38	7.73	x	6
51700	121720	7.5	44.7	1	14.79	9.68	x	5
51700	121806	7.5	43.5	0.09	16.18	9.96	x	5

Log File Name : 06/19/00
Setup Date (MMDDYY) : 062000
Setup Time (HHMMSS) : 090017

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm	Tu N
62000	110044	7.5	45.8	17	8.53	2.58	x	69.7	
62000	110252	7.5	44.6	15.97	8.6	1.38	x	69.4	
62000	110348	7.5	44.5	14.94	8.68	1.09	x	67.7	
62000	110441	7.4	43.7	13.96	8.77	1.16	x	67	
62000	110523	7.4	43.3	12.69	8.88	1.19	x	66.5	
62000	110613	7.4	43.4	12.06	8.98	1.38	x	66.3	
62000	110650	7.4	43.5	11.04	9.3	1.77	x	64.5	
62000	110747	7.4	43	10.04	9.57	2.18	x	64.2	
62000	110838	7.4	42.9	8.75	9.82	2.19	x	65.5	
62000	110918	7.4	43.2	7.34	10.57	2.49	x	66.9	
62000	110956	7.4	42	6.98	10.69	2.47	x	67.6	
62000	111042	7.4	42.3	6	12.09	3.88	x	72.7	
62000	111130	7.4	42.1	4.99	12.83	4.6	x	72.1	
62000	111205	7.4	42.1	4	14.41	5.27	x	78.1	
62000	111254	7.4	42.1	2.41	17.21	6.99	x	78.5	
62000	111345	7.4	41.3	2.01	18.07	8.45	x	75.5	
62000	111354	7.4	41.9	1.82	18.05	8.55	x	76.3	
62000	111446	7.4	41.6	1.03	18.68	9.47	x	76	
62000	111611	7.4	41	0.09	18.74	9.89	x	75.8	

Recovery finished at 083000 132552

Log File Name : 07/12/00
Setup Date (MMDDYY) : 071300
Setup Time (HHMMSS) : 110332

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm	Tu N
71300	123402	7.5	45.2	16.93	8.87	0.54	x	72.6	
71300	123526	7.5	44.7	16.94	8.8	0.34	x	74.2	
71300	123612	7.5	44.6	16	8.81	0.27	x	71.9	
71300	123700	7.5	44.4	15.02	8.85	0.22	x	70.5	
71300	123748	7.4	44.3	14.03	8.94	0.2	x	69.5	
71300	123844	7.5	43.5	13.01	9.07	0.18	x	68.8	
71300	123936	7.4	42.4	12	9.16	0.17	x	67.4	
71300	124015	7.4	42.9	10.99	9.31	0.17	x	66.9	
71300	124110	7.4	42.8	10.01	9.58	0.15	x	67	
71300	124159	7.4	42.3	8.99	10.17	0.24	x	68.4	
71300	124245	7.4	42.2	8.03	10.74	0.33	x	67.7	
71300	124357	7.4	42.3	7.02	11.76	0.51	x	69.1	
71300	124533	7.4	42.3	6.01	12.98	1	x	75.3	
71300	124700	7.4	41.8	4.76	15.2	3.56	x	103	
71300	124840	7.4	41.3	4.02	17.13	5.7	x	87.4	
71300	124952	7.4	41.1	3.01	19.5	9.65	x	84.1	
71300	125051	7.4	41.3	1.36	19.95	10.81	x	83.7	
71300	125201	7.4	41.6	0.34	21.19	10.92	x	84.4	
71300	125245	7.4	41.2	0.04	22.26	10.2	x	0	

Log File Name : 08/15/00
Setup Date (MMDDYY) : 081600
Setup Time (HHMMSS) : 094231

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
81600	113341	7.4	42.7	16.94	9.21	1.97	x	84.2
81600	113429	7.4	42	15.25	9.16	1.35	x	73.6
81600	113513	7.4	40.7	14.99	9.2	0.97	x	73.6
81600	113600	7.4	41.3	14.02	9.3	0.72	x	72.6
81600	113650	7.4	40.6	12.99	9.42	0.49	x	72.4
81600	113731	7.4	39.9	11.99	9.59	0.46	x	72.3
81600	113848	7.4	37.9	11.03	9.78	0.3	x	72.6
81600	113934	7.4	39.3	10	10.02	0.22	x	74.9
81600	114012	7.4	38.6	9.03	10.84	0.19	x	74.1
81600	114055	7.4	39.3	7.57	12.56	0.18	x	81
81600	114144	7.4	36.7	7.01	13.29	0.17	x	82.5
81600	114244	7.4	38.2	6.02	14.37	0.16	x	85.6
81600	114358	7.4	37.8	4.81	16.96	1.04	x	98.2
81600	114517	7.4	37.2	4.06	19.58	3.79	x	100.5
81600	114602	7.3	36.9	3.05	20.74	8.65	x	98.1
81600	114649	7.3	36.9	1.99	21.06	9.35	x	98.6
81600	114733	7.4	37.1	1.01	21.29	9.68	x	98.7
81600	114805	7.4	36.5	0.05	21.81	9.83	x	98.7

Recovery finished at 083000 132824

Log File Name : 09/13/00
Setup Date (MMDDYY) : 091400
Setup Time (HHMMSS) : 114435

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
91400	114828	7.7	59.4	16.04	9.12	0.25	x	101.7
91400	114932	7.6	57.8	14.84	9.19	0.22	x	96.1
91400	115035	7.6	57.9	13.85	9.28	0.18	x	92.3
91400	115109	7.6	57.3	12.97	9.41	0.18	x	88.1
91400	115143	7.6	57.9	11.97	9.65	0.17	x	81.9
91400	115215	7.6	57.3	10.97	9.85	0.16	x	81.6
91400	115300	7.6	57.2	9.45	10.14	0.16	x	75.6
91400	115343	7.6	55.6	8.95	10.75	0.15	x	74.9
91400	115424	7.6	56.9	8	12.01	0.15	x	84.1
91400	115528	7.6	56.2	6.61	14.66	0.14	x	100.9
91400	115608	7.6	56.3	6.01	15.32	1.63	x	105
91400	115716	7.6	53.9	4.43	16.11	3.26	x	107.5
91400	115811	7.6	55.5	3.9	17.34	3.3	x	104.5
91400	120001	7.6	53	2.97	17.71	4.37	x	101.8
91400	120123	7.6	53.1	2.05	18.77	9.74	x	100
91400	120226	7.6	53.8	0.52	19.44	10.3	x	100.6
91400	120324	7.6	54.1	0.03	20.27	9.97	x	100.4

Log File Name : 102300
Setup Date (MMDDYY) : 102400
Setup Time (HHMMSS) : 104722

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units
102400	121606	7.5	45.9	15	9.3	0.66	x
102400	121706	7.5	45.1	12	10.16	0.38	x
102400	121803	7.5	44.5	11	12.25	2.26	x
102400	121848	7.4	43.9	10	12.75	7.44	x
102400	122001	7.4	43.4	7	13.3	8.12	x
102400	122056	7.4	42.4	5	13.31	8.26	x
102400	122156	7.4	42.1	2	13.36	8.5	x
102400	122235	7.4	41.8	1	13.37	8.57	x

No data for November 2000

Log File Name : 12/07/00
Setup Date (MMDDYY) : 120800
Setup Time (HHMMSS) : 101914

Date	Time	IBVSvr4	IB%Svr4	Dep25	Temp	DO	pH	SpC
MMDDYY	HHMMSS	Volts	%Left	meters	øC	mg/l	Units	æS/c
120800	114005	7.2	26.7	17	5.44	9.97	x	
120800	114056	7.2	25.8	16	5.61	10.07	x	
120800	114137	7.2	24.9	15	5.63	10.05	x	
120800	114209	7.2	25.2	14	5.67	10.04	x	
120800	114245	7.2	24.3	13	5.69	10.11	x	
120800	114319	7.2	24.1	12	5.68	10.12	x	
120800	114353	7.2	23	11	5.69	10.1	x	
120800	114441	7.1	22.9	10	5.69	10.08	x	
120800	114553	7.1	22.6	9	5.7	10.04	x	
120800	114625	7.1	21.4	8	5.7	10.11	x	
120800	114703	7.1	22.1	7	5.71	10.15	x	
120800	114741	7.1	20.7	6	5.7	10.13	x	
120800	114808	7.1	20.5	5	5.71	10.13	x	
120800	114839	7.1	18.8	4	5.7	10.09	x	
120800	114914	7.1	19	3	5.7	10.11	x	
120800	114942	7.1	20.3	2	5.7	10.1	x	
120800	115016	7.1	19.7	1	5.71	10.15	x	
120800	115047	7.1	19.5	0	5.73	10.15	x	

Recovery finished at 062801 150818

Log File Name : 01/16/01
Setup Date (MMDDYY) : 011701
Setup Time (HHMMSS) : 115347

Date	Time	IBVSvr4	IB%Svr4	Dep25	Temp	DO	pH	SpC
MMDDYY	HHMMSS	Volts	%Left	meters	øC	mg/l	Units	æS/c
11701	115640	7.1	20.2	16	5.06	10.68	x	
11701	115737	7.1	19.4	14	5.05	10.75	x	
11701	115830	7.1	18.1	12	5.06	10.68	x	
11701	115933	7.1	18.3	10	5.07	10.78	x	
11701	120020	7.1	17.2	8	5.07	10.71	x	
11701	120112	7	16.7	6	5.06	10.73	x	
11701	120233	7	15.6	5	5.05	10.84	x	
11701	120352	7	13.3	4	5.05	10.8	x	
11701	120445	7	14.5	3	5.09	10.8	x	
11701	120539	7	14.3	2	5.16	10.81	x	
11701	120638	7	14	1	5.18	10.84	x	
11701	120748	7	12.8	0	5.2	10.75	x	

Log File Name : 022101
Setup Date (MMDDYY) : 022201
Setup Time (HHMMSS) : 132918

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
22201	133044	7	11.2	17	5.24	11.76	x	68.9
22201	133158	7	9.3	15	5.24	11.81	x	69.1
22201	133240	6.9	8.9	13	5.24	11.81	x	69.2
22201	133321	6.9	8.2	11	5.24	11.8	x	69.2
22201	133401	6.9	8.2	9	5.24	11.79	x	69.4
22201	133439	6.9	7.5	8	5.25	11.77	x	69.5
22201	133511	6.9	7.3	7	5.24	11.82	x	69.1
22201	133620	6.9	6.3	6	5.24	11.83	x	68.9
22201	133700	6.9	4.1	5	5.24	11.84	x	69.4
22201	133811	6.8	4.2	4	5.24	11.82	x	69.5
22201	133858	6.9	4.3	3	5.24	11.86	x	69.2
22201	133930	6.9	3.8	2	5.29	11.85	x	69.2
22201	134003	6.9	3.4	1	5.29	11.82	x	69.5
22201	134050	6.8	2.8	0	5.29	11.82	x	69.5

Recovery finished at 062801 151014

Log File Name : 032001
Setup Date (MMDDYY) : 032101
Setup Time (HHMMSS) : 114918

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
32101	115217	8	89.9	17	6.58	7.97	x	72.1
32101	115308	8.1	87.8	16	6.61	8.71	x	71.6
32101	115349	8.1	89.2	15	6.69	9.35	x	71.9
32101	115438	8.1	89.3	14	6.71	9.64	x	71.9
32101	115533	8.1	89.1	13	6.72	9.69	x	72.2
32101	115621	8.1	88.5	12	6.74	9.78	x	72
32101	115708	8	88.1	11	6.78	9.96	x	72.2
32101	115754	8	87.7	10	7.04	10.03	x	72.3
32101	115856	8	88	9	7.44	10.16	x	73.7
32101	115954	8	86	8	7.67	10.38	x	73.4
32101	120031	8	88.2	7	7.76	10.36	x	73.7
32101	120114	8	87.1	6	7.95	10.73	x	73.6
32101	120149	8	87.4	5	8.08	11.06	x	72.6
32101	120230	8	86.8	4	8.19	11.02	x	72.8
32101	120313	8	86.9	3	8.37	10.96	x	67.6
32101	120408	8	87.1	2	8.48	10.63	x	63
32101	120502	8	86.2	1	8.59	10.64	x	62.8
32101	120556	8	86.4	0	9.91	10.02	x	59.5

Log File Name : 04/25/01
Setup Date (MMDDYY) : 042601
Setup Time (HHMMSS) : 103355

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
42601	103700	7.5	51.5	17	7.33	4.33	x	68.9
42601	103743	7.5	50.6	16	7.45	5.18	x	67.1
42601	103840	7.5	49.5	15	7.47	6.23	x	66.3
42601	103935	7.5	47.4	14	7.53	6.42	x	65.8
42601	104013	7.5	49.4	13	7.59	6.59	x	64.5
42601	104053	7.5	48.2	12	7.65	7.14	x	64.5
42601	104124	7.5	48.3	11	7.69	7.33	x	63.7
42601	104209	7.5	48	10	7.74	7.35	x	63.2
42601	104245	7.5	47.8	9	7.82	7.6	x	61.6
42601	104325	7.5	47.3	8	7.9	7.92	x	61.2
42601	104425	7.5	47	7	8.15	8.21	x	60
42601	104513	7.5	46.9	6	8.36	8.66	x	59.6
42601	104556	7.5	46.3	5	8.73	8.88	x	63.3
42601	104641	7.5	44.1	4	9.57	8.84	x	62.6
42601	104752	7.4	44.3	3	10.29	9.62	x	63.1
42601	104857	7.5	45.6	2	11.8	10.7	x	65
42601	104954	7.5	44.8	1	12.94	11.11	x	62.4
42601	105051	7.5	45	0	13.48	11.27	x	62.2

Recovery finished at 062801 151225

Log File Name : 052401
Setup Date (MMDDYY) : 052501
Setup Time (HHMMSS) : 101457

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
52501	102117	7.2	25.6	17	7.65	2.02	x	71.8
52501	102208	7.2	26.7	16	7.73	2.53	x	69.7
52501	102309	7.2	26.2	15	7.77	2.82	x	69
52501	102411	7.2	25.4	14	7.83	3.45	x	67.6
52501	102501	7.2	25.7	13	7.95	4.21	x	66.1
52501	102545	7.2	24.7	12	8.1	4.12	x	65.7
52501	102653	7.2	23.9	11	8.25	3.86	x	65.8
52501	102731	7.2	23.6	10	8.39	4.44	x	64.6
52501	102853	7.1	22.9	9	8.71	4.23	x	63.4
52501	103034	7.1	20.6	8	8.95	4.17	x	63.6
52501	103127	7.1	21.9	7	9.51	4.33	x	63.5
52501	103200	7.1	21.7	6	10.12	4.69	x	63.9
52501	103317	7.1	20.3	5	10.73	5.45	x	63.6
52501	103433	7.1	20.2	4	12.4	7.15	x	68.9
52501	103523	7.1	20.2	3	14.87	10.57	x	66.3
52501	103633	7.1	19.6	2	16.98	11.77	x	69.4
52501	103717	7.1	18.8	1	19.27	11.37	x	68
52501	103811	7.1	18.7	0	19.49	11.24	x	0

Log File Name : 062001
Setup Date (MMDDYY) : 062101
Setup Time (HHMMSS) : 090200

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
62101	102424	8.1	96.1	17	7.98	0.6	x	73.2
62101	102547	8.1	95.6	16	7.99	0.48	x	72.2
62101	102628	8.1	95.5	15	8.01	0.51	x	71.8
62101	102656	8.1	95.1	14	8.01	0.64	x	70.7
62101	102738	8.1	93.7	13	8.05	0.67	x	70.6
62101	102819	8.1	94.5	12	8.1	0.82	x	69.4
62101	102922	8.1	94	11	8.34	1.09	x	67.8
62101	103024	8.1	93.2	10	8.69	1.59	x	65.2
62101	103118	8.1	94.3	9	9.31	1.63	x	66.2
62101	103150	8.1	94.2	8	9.98	1.37	x	65
62101	103224	8.1	93.4	7	10.63	1.51	x	65.9
62101	103325	8.1	92.7	6	11.86	2.26	x	67.9
62101	103358	8.1	93.4	5	13.02	3.13	x	76
62101	103508	8.1	92.7	4	14.22	6.07	x	79.8
62101	103708	8.1	92.4	3	17.99	9.32	x	72.6
62101	103801	8.1	92.3	2	18.93	9.73	x	72.6
62101	103857	8.1	92.1	1	19.32	9.75	x	73.2
62101	103943	8.1	91.8	0	19.93	9.69	x	72.5

Recovery finished at 062301 112628

Log File Name : 071101
Setup Date (MMDDYY) : 071201
Setup Time (HHMMSS) : 091115

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm
71201	103101	7.2	27.1	17	8.02	0.18	x	78.3
71201	103206	7.2	27.8	16	8.1	0.16	x	75.4
71201	103302	7.2	27	15	8.17	0.15	x	74.6
71201	103413	7.2	26.6	14	8.24	0.14	x	71.7
71201	103508	7.2	24.9	13	8.3	0.14	x	70.9
71201	103603	7.2	24.4	12	8.44	0.15	x	70.4
71201	103647	7.2	23.5	11	8.6	0.16	x	70.1
71201	103756	7.1	22.4	10	8.83	0.21	x	69.4
71201	103837	7.1	21.6	9	9.27	0.28	x	68.3
71201	103933	7.1	20.3	8	9.85	0.13	x	68.4
71201	104033	7.1	20.2	7	11	0.11	x	69.1
71201	104112	7.1	19.4	6	12.55	0.18	x	72
71201	104311	7.1	17.9	5	14.41	1.43	x	75
71201	104529	7	15.9	4	16.91	3.42	x	82.7
71201	104657	7	14.4	3	21.88	8.96	x	79.8
71201	104823	7	13.2	2	22.46	10.7	x	79.9
71201	104935	7	10.7	1	22.67	11.17	x	80
71201	105034	7	11.4	0	23.16	10.97	x	80

Log File Name : 082101
Setup Date (MMDDYY) : 082201
Setup Time (HHMMSS) : 092918

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm	Turb NTUs
82201	103816	7.6	55.3	17	8.23	0.5	x	99.8	
82201	103951	7.6	54.6	16	8.28	0.33	x	79.2	
82201	104049	7.6	53.9	15	8.34	0.27	x	77.3	
82201	104157	7.6	54.3	14	8.44	0.25	x	75.7	
82201	104301	7.6	53.6	13	8.53	0.22	x	74.6	
82201	104426	7.6	53.1	12	8.64	0.2	x	73.9	
82201	104718	7.5	52.4	11	8.84	0.14	x	73.5	
82201	104819	7.6	52.1	10	9.18	0.15	x	72.9	
82201	104914	7.6	51.9	9	9.82	0.14	x	72.8	
82201	104958	7.6	50.8	8	10.95	0.12	x	74.6	
82201	105150	7.6	52.5	7	12.2	0.13	x	77	
82201	105257	7.6	51.4	6	13.86	0.15	x	81.6	
82201	105433	7.6	51	5	17.16	0.14	x	90.4	
82201	105553	7.6	51.1	4	20.93	7.7	x	86.6	
82201	105911	7.6	50.9	3	20.98	8.22	x	86.2	
82201	110040	7.5	51.2	2	21.01	8.58	x	86.8	
82201	110137	7.5	50.4	1	21.23	8.71	x	86.8	
82201	110321	7.5	51.1	0	21.27	8.91	x	86.6	

Power loss from 102401 114819 to 102601 081814

Log File Name : 091701
Setup Date (MMDDYY) : 091801
Setup Time (HHMMSS) : 103243

Date MMDDYY	Time HHMMSS	IBVSvr4 Volts	IB%Svr4 %Left	Dep25 meters	Temp øC	DO mg/l	pH Units	SpCond æS/cm	Turb NTUs
91801	103348	7.6	53.6	17	8.33	0.22	x	112.6	
91801	103511	7.6	53.2	16	8.37	0.2	x	105.9	
91801	103628	7.6	52.4	15	8.39	0.17	x	101.5	
91801	103758	7.6	51.6	14	8.45	0.16	x	95.3	
91801	103918	7.6	52	13	8.55	0.15	x	89.2	
91801	104023	7.6	51.5	12	8.78	0.14	x	76.2	
91801	104131	7.5	51.5	11	9.07	0.14	x	75.5	
91801	104309	7.5	50.5	10	9.69	0.13	x	74.4	
91801	104410	7.5	50.4	9	10.5	0.13	x	76.2	
91801	104602	7.5	49.6	8	11.42	0.13	x	83	
91801	104729	7.5	49.9	7	13.98	0.12	x	96.1	
91801	105001	7.5	49.4	6	16	0.12	x	98.3	
91801	105059	7.5	48.6	5	17.51	0.13	x	94.6	
91801	105145	7.5	48	4	19.37	3.45	x	94.2	
91801	105412	7.5	48.2	3	20.54	8.76	x	87.8	
91801	105626	7.5	48.5	2	20.76	9.74	x	88.7	
91801	105758	7.5	47.6	1	20.76	9.81	x	87.7	
91801	105938	7.5	47.7	0	20.72	9.86	x	87.9	
102401	113722	7	9.8	17	8.37	0.24	x	146.7	

Appendix 4: WY 2000 and WY 2001 Thalweg comparison and Multiple-grab comparison data

WY 2000 and WY 2001 QC Monitoring
Thalweg Comparison Samples

Inlet

WY 2000

Date	TP Sigma	TP Thalweg	TSS Sigma	TSS Thalweg
02-Nov-99	0.078	0.051	36	<5
24-Nov-99	0.038	0.034	6	<5
16-Dec-99	0.048	<.010	5	<5
10-Mar-00	0.019	0.027	9.5	<5
14-Apr-00	0.076	0.079	15	11
08-Aug-00	0.123	0.042	24.5	6
19-Sep-00	0.021	0.036	<5	<5

WY 2001

Date	TP Sigma	TP Thalweg	TSS Sigma	TSS Thalweg
02-Jan-01	0.047	0.027	8	ND
01-Feb-01	0.047	0.038	15	ND
30-Mar-01	0.052	0.036	9	5
02-Jul-01	0.053	0.032	7	9
21-Aug-01	0.056	0.048	5	4

Outlet

WY 2000

Date	TP Sigma	TP Thalweg	TSS Sigma	TSS Thalweg
07-Jan-00	0.040	0.035	ND	ND
20-Jan-00	ND	0.029	ND	ND
06-Mar-00	0.032	0.030	7	ND
11-May-00	0.030	0.026	ND	ND
15-Jun-00	0.035	0.023	9	ND
08-Aug-00	0.012	0.020	ND	ND
09/19/00	0.055	0.044	6	ND

WY 2001

Date	TP Sigma	TP Thalweg	TSS Sigma	TSS Thalweg
02-Jan-01	0.038	0.045	6	ND
01-Jun-01	0.076	0.067	22	4
02-Jul-01	0.058	0.024	15	ND
21-Aug-01	0.036	0.035	8	ND

WY 2000 and WY 2001 QC Monitoring
Multiple-Grab Comparison Samples*

Date	TP Grab 1	TP Grab 2	TP Thalweg	TSS Grab 1	TSS Grab 2	TSS Thalweg
08-Aug-00	0.123	0.064	0.042	25	11	6
01-Feb-01	0.047	0.039	0.038	15	7	3
30-Mar-01	0.052	0.038	0.036	9	4	5

*Grab 1 and Grab 2 collected in immediate succession using manual sample mode of Sigma sampler. Thalweg collected from mid-channel by hand.

Appendix 5: WY 2000 and WY 2001 Gage Comparison data

WY 2000 and WY 2001 QC: Gage Comparison

WY 2000 Sigma vs. existing CCPW Stevens gage:

Date	Sigma	Stevens	Difference
02-Nov-99	1.02	0.52	0.5
13-Jan-00	3.92	3.46	0.46
01-May-00	1.26	0.78	0.48

average difference = 0.48 ft

WY 2001 Sigma vs. LLRP Stevens backup gage:

	Date	Sigma	Stevens	Difference
initial setup date --	01-May-00	1.26	1.35	0.09
	02-Oct-00	1.06	1.16	0.10
	21-Nov-00	0.99	1.06	0.08
	28-Feb-01	1.16	1.23	0.07
	01-May-01	2.10	2.21	0.11
	27-Sep-01	0.75	0.85	0.10

average difference = 0.09 ft

Appendix 6: 1983-2001 WQStat Plus database, Lacamas Lake site L1

[Lacamas]	□	□	□										
				TSS (mg/L)	NH3 (mg/L)	TKN (mg/L)	OP (mg/L)	TP (mg/L)	NO2+NO3 (mg/L)	pH (units)	DO (mg/L)	Cond (uS/cm)	Temp (C)
				n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
L1_top	u												
	12/06/83	n/a	R5	1.6	0.140	0.570	0.034	0.100	0.780	8	n/a	65	6.1
	01/05/84	n/a	R5	34	0.140	0.570	0.046	0.100	0.860	7.3	n/a	69	3.5
	02/14/84	n/a	R5	16	0.140	0.360	0.052	0.098	0.830	6.9	9.2	84	7.5
	03/08/84	n/a	R5	11	0.070	0.570	0.054	0.071	0.870	7.2	9	84	9.7
	04/10/84	n/a	R5	n/a	0.140	0.280	0.026	0.036	0.670	6.9	10.8	90	9.6
	05/03/84	1	R5	7.1	0.140	0.430	0.030	0.089	0.600	7.5	10.9	83	11.8
	05/16/84	1	R5	5.5	0.070	0.430	0.023	0.064	0.590	7.5	10.6	96	14.5
	05/30/84	1	R5	8	0.070	0.430	0.039	0.036	0.640	7.3	11.3	107	16
	06/13/84	2	R5	16	0.100	0.360	0.016	0.120	0.250	8.9	14.6	76	15.6
	06/26/84	2	R5	4.5	0.360	0.780	0.048	0.140	0.620	6.9	8.7	82	20
	07/10/84	3	R5	18	0.140	0.850	0.023	0.035	0.250	9.4	13.1	88	21.6
	07/24/84	3	R5	9	0.140	0.570	0.025	0.031	0.250	9.1	12.7	78	22.9
	08/07/84	4	R5	6	0.070	0.360	0.028	0.042	0.260	8.3	9.4	81	23.2
	08/19/84	4	R5	5	0.070	0.360	0.009	0.042	n/a	8.7	10.6	83	22.7
	09/25/84	n/a	R5	6.5	0.210	0.360	0.030	0.036	n/a	7.3	10.4	83	17.3
	10/25/84	n/a	R5	8	0.430	1.000	0.029	0.035	0.140	7	8.1	86	12
	11/19/84	n/a	R5	8.5	0.070	0.500	0.035	0.067	0.760	6.6	9.7	55	8.7
	07/24/91	5	L4	n/a	0.033	0.647	0.003	0.033	0.453	n/a	n/a	88	n/a
	07/31/91	5	L4	n/a	0.038	0.372	n/a	0.017	0.489	8.3	9.5	89.5	24.8
	08/09/91	6	L4	n/a	0.036	0.319	0.004	0.021	0.352	8.8	10.8	81.5	24
	08/20/91	6	L4	n/a	0.043	0.345	0.003	0.015	0.045	9.4	10.9	85.5	25.5
	08/29/91	6	L4	n/a	0.061	0.610	0.002	0.022	0.096	9.4	10.3	120	21
	09/06/91	n/a	L4	n/a	0.068	0.431	<.002	0.036	0.200	8.6	11.5	120	23.8
	10/03/91	n/a	L4	n/a	0.027	0.479	<.002	0.029	0.036	8.1	11.1	110	19.2
	11/06/91	n/a	L4	n/a	0.180	0.529	n/a	0.046	0.481	6.5	8.4	118	10
	01/22/92	n/a	L4	n/a	n/a	n/a	n/a	0.061	n/a	n/a	13.6	n/a	5
	04/03/92	n/a	L4	n/a	<.02	0.567	0.005	0.030	0.843	7.6	12.5	74	15.2
	05/06/92	n/a	L4	n/a	0.038	0.488	n/a	0.063	0.562	8.3	14.4	70	20.2
	06/05/92	7	L4	n/a	<.020	0.300	0.003	0.017	0.484	8.3	10.1	84	21.2
	06/19/92	7	L4	n/a	0.031	0.383	n/a	0.024	0.427	n/a	12.2	85	21.5
	07/08/92	8	L4	n/a	0.027	0.516	0.004	0.023	0.131	9.4	10.4	89	22.1
	07/15/92	8	L4	n/a	0.030	0.606	n/a	0.024	0.093	9.3	11	90	23
	08/06/92	n/a	L4	n/a	0.048	0.764	0.006	0.028	0.082	9.6	9.9	99	23.8
	09/03/92	n/a	L4	n/a	<.02	0.693	0.003	0.032	0.064	9.1	11.4	98	21.8
	10/08/92	n/a	L4	n/a	0.064	0.456	0.003	0.021	0.067	7.5	8.2	103	16
	11/04/92	n/a	E5	n/a	0.130	0.420	0.010	0.030	0.170	n/a	7.2	n/a	12.2
	12/08/92	n/a	E5	n/a	0.100	0.430	0.020	0.030	1.060	n/a	n/a	n/a	n/a
	01/05/93	n/a	L8	n/a	0.032	0.310	0.019	0.034	1.220	6.8	12.3	n/a	3.8
	02/01/93	n/a	L8	n/a	0.075	0.320	0.035	0.038	1.240	7	13.6	71	4.5
	03/09/93	n/a	L8	n/a	0.041	0.220	0.015	0.038	1.150	7.1	12	n/a	5.8
	04/07/93	n/a	L8	n/a	<.020	0.228	0.014	0.048	0.842	7	10.5	54	10.8
	05/04/93	n/a	L8	n/a	0.036	0.286	0.012	0.035	0.682	6.9	11.9	58	13
	06/03/93	n/a	L8	n/a	0.026	0.583	0.007	0.054	0.537	7.8	12.1	69	19.5
	07/12/93	n/a	L8	n/a	0.030	0.132	0.005	0.020	0.570	7.7	10.4	83	19
	08/11/93	n/a	L8	n/a	<.020	0.534	0.014	0.030	0.536	n/a	12	97	22.8
	09/16/93	n/a	L8	n/a	0.038	0.497	0.007	0.020	0.324	8.2	10.8	96	21
	10/06/93	n/a	L8	n/a	<.020	0.581	0.014	0.048	0.104	8.6	10.5	101	17
	11/08/93	n/a	L8	n/a	0.103	0.340	0.013	0.045	0.253	7.2	6.7	102	11.5
	12/15/93	n/a	L8	n/a	0.063	0.290	0.029	0.081	1.540	n/a	n/a	76	n/a
	04/11/94	n/a	L8	n/a	n/a	0.302	0.006	0.046	0.748	7.8	12.9	63	12.5
	05/10/94	n/a	L8	n/a	n/a	0.399	0.004	0.026	0.631	7.4	10.5	73	18.9
	06/14/94	n/a	L8	n/a	n/a	0.292	0.011	0.026	0.335	7.6	10.5	79	18.5
	07/12/94	n/a	L8	n/a	n/a	0.393	0.005	0.009	0.222	8.4	9.8	86	22.2
	08/09/94	n/a	L8	n/a	n/a	0.949	0.004	0.029	0.023	9.4	11.2	94	22.5
	09/13/94	n/a	L8	n/a	n/a	0.570	0.004	0.022	0.049	8.6	9.4	96	19.7
	10/11/94	n/a	L8	n/a	n/a	0.628	0.005	0.026	0.041	7.6	8.4	97	16.5
	04/21/95	n/a	B6	6	<.010	0.480	n/a	0.041	0.770	6.8	11.4	72	11.2
	05/24/95	n/a	B6	<5	0.010	0.510	n/a	0.033	0.330	9.9	15.4	79	18.6
	06/16/95	n/a	B6	5	0.010	0.990	n/a	0.060	0.630	8.6	10.7	83	18.7
	07/18/95	n/a	B6	<5	<.010	0.450	n/a	0.032	0.440	8.7	10.6	84	25
	08/17/95	n/a	B6	9	<.005	0.830	n/a	0.039	0.240	9.3	11.8	84	20.5
	09/22/95	n/a	B6	5	0.150	0.820	n/a	0.030	0.230	7.1	6.8	100	17.9
	10/20/95	n/a	B6	5	0.066	0.790	n/a	0.028	0.510	6.5	8.2	92	13.6
	11/09/95	n/a	B6	20	0.130	0.830	n/a	0.066	n/a	6.4	7.6	78	10.1
	02/22/96	n/a	B6	5	0.010	0.280	n/a	0.310	1.000	6.2	12.1	57	7.9
	03/20/96	n/a	B6	5	0.057	0.530	n/a	0.040	1.100	6.6	10.6	62	10.9
	04/28/96	n/a	B6	5	<.010	0.887	n/a	0.026	1.100	6.7	10.6	58	12.7
	05/22/96	n/a	B6	10	<.010	0.420	n/a	0.030	0.700	6.2	9.3	72	15.2
	09/30/98	n/a	80	<5	<0.1	<1.0	<.025	0.029	<0.1	8.7	8.8	94	18.8
	10/29/98	n/a	80	<5	0.192	<1.0	<.025	0.041	0.186	7.4	7.1	49	12.7
	12/30/98	n/a	80	<10	0.110	<1.0	0.048	0.030	1.290	6.7	9.5	22	9
	02/09/99	n/a	80	<5	0.245	<1.0	0.043	0.041	0.960	6.7	10.8	24	6.4
	04/02/99	9	80	<5	<0.1	<1.0	<.025	0.037	0.880	6.8	11.7	33	10.4
	04/22/99	9	80	<5	<0.1	<1.0	<.025	0.035	0.873	7.2	11.3	38	12
	05/27/99	n/a	80	<5	<0.1	<1.0	0.006	0.020	0.689	7.1	10.1	39	19.1
	06/14/99	10	80	<10	<0.1	<1.0	0.011	0.018	0.473	8.1	10.5	41	21.3
	06/30/99	10	80	<5	<0.1	<1.0	0.012	0.020	0.522	7.7	9.9	87	18.9
	07/08/99	11	80	<10	<0.1	<1.0(j)	0.007	0.022	0.925	8.4	11.2	87	20
	07/26/99	11	80	<10	0.417	<1.0	0.014	0.025	0.255	8.9	10.6	89	22.2
	08/12/99	12	80	<5	0.166	<1.0	0.009	0.044(j)	0.218	7.7	7.2	95	22.1

	08/30/99	12	S0	8	0.240	<1.0	0.018	0.047	0.284	8	8.7	96	21
	09/15/99	13	S0	<10	0.363(a)	<1.0	0.013	0.024	0.283	7.4	9.6	99	18.6
	09/29/99	13	S0	<10	<0.1	<1.0	0.012	0.025	0.234	6.9	8	100	18.1
	10/22/99	n/a	S1	<10	<0.1	<1.0	<0.002	0.022	0.253	n/a	7.9	98	13.5
	11/18/99	n/a	S1	<5	0.130	<1.0	0.019	0.033	0.523	n/a	7.6	101	10.9
	12/22/99	n/a	S1	<10	<0.1	1.130	0.024	0.032	0.960	n/a	9.1	46	8.3
	01/26/00	n/a	S1	<5	<0.05	0.580	0.014	<0.01	0.959	n/a	11	51	5.2
	02/28/00	n/a	S1	<5	<0.05	0.644	0.013	0.053	0.900	n/a	10.6	56	7.7
	03/23/00	n/a	S1	<5	<0.05	<0.5	0.008	0.024	0.830	n/a	10.2	62	8.6
	04/18/00	n/a	S1	<5	<0.05	0.745	0.006	0.033	1.240	n/a	11.1	73	13.5
	05/16/00	n/a	S1	<5	<0.05	0.640	<0.005	0.024	0.573	n/a	9.7	59	14.8
	06/19/00	n/a	S1	10	<0.05	0.924	<0.005	0.043	0.337	n/a	9.3	78	18.7
	07/12/00	n/a	S1	11	<0.05	0.738	0.009	0.031	0.222	n/a	10.9	84	21.2
	08/15/00	n/a	S1	9	<0.05	0.835	<0.005	0.027	0.051	n/a	9.7	99	21.3
	09/13/00	n/a	S1	<4	<0.05	0.934	0.024	0.034	0.048	n/a	10.3	101	19.4
	10/23/00	n/a	S2	7	<0.030	0.785	0.013	0.039	.073(a)	n/a	8.6	97	13.4
	11/01/00	n/a	S2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	12/07/00	n/a	S2	3	0.101	0.739	0.008	0.029	0.600	n/a	10.2	86	5.7
	01/16/01	n/a	S2	<5	<0.030	0.583	0.019	0.033	1.020	n/a	10.8	70	3.2
	02/21/01	n/a	S2	<5(k)	<0.030	0.643	0.020	0.023	1.360	n/a	11.8	70	5.3
	03/20/01	n/a	S2	6	<0.030	0.727	0.013	0.045	1.570	n/a	10.6	63	8.6
	04/25/01	n/a	S2	3	<0.030	<0.500	0.018	0.025	0.902(k)	n/a	11	62	12.9
	05/24/01	n/a	S2	8	<0.030	0.518	<0.005	0.024	0.288	n/a	11.4	68	19.3
	06/20/01	n/a	S2	4	<0.030	0.519(a)	0.010	0.026	0.478	n/a	9.8	73	19.3
	07/11/01	n/a	S2	7	<0.030	0.727	0.006	0.019	0.040(a)	n/a	11.2	80	22.7
	08/21/01	n/a	S2	8	<0.030	0.560	<0.010	0.021	0.018	n/a	8.7	87	21.2
	09/17/01	n/a	S2	4	<0.030	0.714(a)	0.018	0.039	<0.005	n/a	9.8	88	20.3
L1_mid	u												
	01/05/93	n/a	L8	n/a	0.066	0.280	0.018	0.041	1.230	6.8	n/a	n/a	n/a
	02/01/93	n/a	L8	n/a	0.067	0.290	0.024	0.043	1.270	7.1	n/a	63	n/a
	03/09/93	n/a	L8	n/a	0.040	0.250	0.014	0.043	1.160	7.1	n/a	n/a	n/a
	04/07/93	n/a	L8	n/a	0.023	0.243	0.014	0.033	0.837	6.7	n/a	34	n/a
	05/04/93	n/a	L8	n/a	0.038	0.153	0.011	0.030	0.716	7	n/a	38	n/a
	06/03/93	n/a	L8	n/a	0.058	0.149	0.017	0.036	0.639	6.9	n/a	63	n/a
	07/12/93	n/a	L8	n/a	0.030	0.080	0.007	0.024	0.683	6.7	n/a	79	n/a
	08/11/93	n/a	L8	n/a	0.074	0.346	0.019	0.028	0.640	n/a	n/a	88	n/a
	09/16/93	n/a	L8	n/a	0.201	0.482	0.013	0.044	0.233	6.7	n/a	87	n/a
	10/06/93	n/a	L8	n/a	0.212	0.546	0.014	0.048	0.174	6.8	n/a	93	n/a
	11/08/93	n/a	L8	n/a	0.105	0.340	0.005	0.043	0.255	7.1	n/a	103	n/a
	09/30/98	n/a	S0	<5	0.233	<1.0	<.025	0.022	0.275	n/a	n/a	n/a	n/a
	10/29/98	n/a	S0	<5	0.183	<1.0	<.025	0.024	0.194	n/a	n/a	n/a	n/a
	12/14/98	n/a	S0	<10	0.115	<1.0	0.062	0.062	1.100	n/a	n/a	n/a	n/a
	02/09/99	n/a	S0	<5	<0.1	<1.0	0.037	0.029	1.000	n/a	n/a	n/a	n/a
	04/02/99	1	S0	<5	<0.1	<1.0	<.025	<.035	0.962	n/a	n/a	n/a	n/a
	04/22/99	1	S0	<5	0.101	<1.0	<.025	<.035	0.973	n/a	n/a	n/a	n/a
	05/27/99	n/a	S0	<5	<0.1	<1.0	0.011	0.026	0.847	n/a	n/a	n/a	n/a
	06/14/99	2	S0	<10	<0.1	<1.0	0.009	0.018	0.904	n/a	n/a	n/a	n/a
	06/30/99	2	S0	<5	0.103	<1.0	0.012	0.023	0.842	n/a	n/a	n/a	n/a
	07/08/99	3	S0	<10	<0.1	<1.0	0.008	0.022	0.926	n/a	n/a	n/a	n/a
	07/26/99	3	S0	<10	<0.1	<1.0	0.009	0.039	0.831	n/a	n/a	n/a	n/a
	08/12/99	4	S0	<5	0.179	<1.0	0.005	0.135	0.838	n/a	n/a	n/a	n/a
	08/30/99	4	S0	<5	0.161	<1.0	0.014	0.042	0.532	n/a	n/a	n/a	n/a
	09/15/99	5	S0	<10	<0.1	<1.0	0.010	0.026	0.534	n/a	n/a	n/a	n/a
	09/29/99	5	S0	<10	0.182	<1.0	0.011	0.023	0.382	n/a	n/a	n/a	n/a
	10/22/99	n/a	S1	<10	0.139	<1.0	0.003	0.025	0.328	n/a	n/a	n/a	n/a
	11/18/99	n/a	S1	8	0.124	<1.0	0.034	0.049	0.632	n/a	n/a	n/a	n/a
	12/22/99	n/a	S1	<10	<0.1	0.980	0.025	0.028	0.970	n/a	n/a	n/a	n/a
	01/26/00	n/a	S1	<5	<0.05	<0.5	0.014	<0.01	0.985	n/a	n/a	n/a	n/a
	02/28/00	n/a	S1	<5	<0.05	0.574	0.011	0.044	0.915	n/a	n/a	n/a	n/a
	03/23/00	n/a	S1	<5	<0.05	<0.5	0.008	0.019	0.775	n/a	n/a	n/a	n/a
	04/18/00	n/a	S1	<5	<0.05	0.613	0.006	0.023	0.865	n/a	n/a	n/a	n/a
	05/16/00	n/a	S1	<5	<0.05	0.619	0.014	0.040	0.768	n/a	n/a	n/a	n/a
	06/19/00	n/a	S1	7	<0.05	0.789	<0.005	0.035	0.600	n/a	n/a	n/a	n/a
	07/12/00	n/a	S1	<5	0.062	0.837	0.008	0.030	0.899	n/a	n/a	n/a	n/a
	08/15/00	n/a	S1	<5	<0.05	0.780	<0.005	0.032	0.408	n/a	n/a	n/a	n/a
	09/13/00	n/a	S1	<4	0.052	0.560	<0.005	0.018	0.286	n/a	n/a	n/a	n/a
	10/23/00	n/a	S2	30	<0.030	0.949	<0.010	0.033	0.130	n/a	n/a	n/a	n/a
	11/01/00	n/a	S2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	12/07/00	n/a	S2	3	0.098	0.611	0.008	0.031	0.580	n/a	n/a	n/a	n/a
	01/16/01	n/a	S2	<5	<0.030	0.579	0.018	0.016	1.080	n/a	n/a	n/a	n/a
	02/21/01	n/a	S2	<5	<0.030	<0.500	0.014	0.017(a)	1.600	n/a	n/a	n/a	n/a
	03/20/01	n/a	S2	3	<0.030	<0.500	0.013	0.020	1.370	n/a	n/a	n/a	n/a
	04/25/01	n/a	S2	4	<0.030	<0.500	0.017	0.027	1.130	n/a	n/a	n/a	n/a
	05/24/01	n/a	S2	7	<0.030	<0.500	<0.005	0.039	0.295	n/a	n/a	n/a	n/a
	06/20/01	n/a	S2	4	<0.030	0.578	0.014	0.037	0.639	n/a	n/a	n/a	n/a
	07/11/01	n/a	S2	6	<0.030	0.736	0.008	0.029	0.342	n/a	n/a	n/a	n/a
	08/21/01	n/a	S2	7	<0.030	<0.500	<0.010	0.026	0.096	n/a	n/a	n/a	n/a
	09/17/01	n/a	S2	3	0.180	0.534	0.024	0.037	0.046	n/a	n/a	n/a	n/a
L1_bot	u												
	12/06/83	n/a	R5	1.6	0.140	0.570	0.034	0.100	0.780	7.1	n/a	65	6
	01/05/84	n/a	R5	34	0.140	0.570	0.046	0.100	0.860	6.9	n/a	69	3.9
	02/14/84	n/a	R5	16	0.140	0.380	0.052	0.098	0.830	6.9	9.4	84	6.4
	03/08/84	n/a	R5	11	0.070	0.570	0.054	0.071	0.870	7	8.2	84	7.6
	04/10/84	n/a	R5	n/a	0.140	0.280	0.026	0.056	0.670	6.8	6	90	8.1

05/03/84	1	R5	7.1	0.140	0.430	0.030	0.089	0.650	7.2	4.5	83	9.5
05/16/84	1	R5	7	0.070	0.280	0.037	0.103	0.740	7	3.6	93	9.9
05/30/84	1	R5	4	0.140	0.360	0.064	0.082	0.760	6.8	0.4	100	9.8
06/13/84	2	R5	2.5	0.070	0.210	0.057	0.130	0.690	7.4	0.9	76	10.1
06/26/84	2	R5	3	0.430	0.640	0.052	0.120	0.720	6.5	0.2	77	10.2
07/10/84	3	R5	6.5	0.140	0.640	0.039	0.049	0.520	7.8	0.2	83	10.3
07/24/84	3	R5	0.5	0.140	0.640	0.039	0.042	0.500	7.2	0.2	63	10.6
08/07/84	4	R5	15	0.210	0.360	0.048	0.053	0.220	6.9	0.3	73	10.5
08/19/84	4	R5	1	0.710	0.780	0.026	0.093	0.240	6.9	0.2	82	10.5
09/25/84	n/a	R5	n/a	0.570	0.710	0.190	0.220	n/a	6.5	0.2	88	10.6
10/25/84	n/a	R5	8	0.430	1.000	0.029	0.035	0.140	6.5	0.2	86	10.3
11/19/84	n/a	R5	8.5	0.070	0.500	0.035	0.067	0.760	6.9	9.2	55	8.2
07/24/91	5	L4	n/a	0.132	0.313	0.029	0.063	0.489	n/a	n/a	65	n/a
07/31/91	5	L4	n/a	0.092	0.284	n/a	0.056	0.532	6.7	0	64	9.2
08/09/91	6	L4	n/a	0.194	0.187	0.017	0.057	0.251	6.8	0.05	55	9
08/20/91	6	L4	n/a	0.275	0.253	0.019	0.088	0.170	7	0.05	66	9.2
08/29/91	6	L4	n/a	0.428	0.403	0.024	0.049	0.153	7.1	0.1	81	9.2
09/06/91	n/a	L4	n/a	0.408	0.673	0.043	0.023	0.089	6.9	0.1	76	9.5
10/03/91	n/a	L4	n/a	0.142	0.625	0.106	0.107	0.080	6.2	0.1	108	9.5
11/06/91	n/a	L4	n/a	0.214	0.436	n/a	0.097	0.321	6.4	7.05	129	9
01/22/92	n/a	L4	n/a	n/a	n/a	n/a	0.066	n/a	n/a	13.5	86	4.8
04/03/92	n/a	L4	n/a	0.214	0.625	0.018	0.056	0.063	6.6	6.6	68	9.5
05/06/92	n/a	L4	n/a	0.114	0.171	n/a	0.068	0.724	6.5	4.4	70	10.5
06/05/92	7	L4	n/a	0.122	0.341	0.026	0.111	0.558	6.7	0.05	76	10.8
06/19/92	7	L4	n/a	0.166	0.303	n/a	0.067	0.466	6.7	0.1	76	10.8
07/08/92	8	L4	n/a	0.266	0.378	0.013	0.048	0.278	6.7	0.05	80	10.2
07/15/92	8	L4	n/a	0.227	0.572	n/a	0.044	0.067	7.2	0.05	86	10.5
08/06/92	n/a	L4	n/a	0.485	0.613	0.033	0.098	0.082	7	0.05	76	10.5
09/03/92	n/a	L4	n/a	0.649	0.805	0.123	0.160	0.133	6.9	0.1	82	10.8
10/08/92	n/a	L4	n/a	1.020	1.100	0.214	0.343	< .01	6.9	0.1	91	10.8
11/04/92	n/a	R5	n/a	0.960	1.190	0.060	0.170	0.080	n/a	0.2	n/a	10.5
12/08/92	n/a	R5	n/a	0.100	0.380	0.020	0.030	1.060	n/a	11.8	n/a	3.5
01/05/93	n/a	L8	n/a	0.039	0.340	0.018	0.040	1.230	6.8	n/a	n/a	n/a
02/01/93	n/a	L8	n/a	0.071	0.320	0.023	0.040	1.260	7	n/a	67	n/a
03/09/93	n/a	L8	n/a	0.043	0.190	0.013	0.038	1.160	7	n/a	n/a	n/a
04/07/93	n/a	L8	n/a	0.057	0.211	0.015	0.045	0.969	6.9	n/a	63	n/a
05/04/93	n/a	L8	n/a	0.041	0.171	0.015	0.035	0.899	6.8	n/a	64	n/a
06/03/93	n/a	L8	n/a	0.041	0.263	0.016	0.032	0.797	6.7	n/a	65	n/a
07/12/93	n/a	L8	n/a	0.176	0.178	0.014	0.036	0.424	6.6	n/a	71	n/a
08/11/93	n/a	L8	n/a	0.275	0.477	0.020	0.051	0.231	n/a	n/a	74	n/a
09/16/93	n/a	L8	n/a	0.470	0.693	0.059	0.106	< .010	6.6	n/a	75	n/a
10/06/93	n/a	L8	n/a	0.633	1.013	0.123	0.170	0.033	6.9	n/a	82	n/a
11/08/93	n/a	L8	n/a	0.474	0.757	0.026	0.098	0.147	6.8	n/a	94	n/a
12/15/93	n/a	L8	n/a	0.116	0.388	0.040	0.075	1.060	n/a	n/a	91	n/a
09/30/98	n/a	S0	5	0.166	<1.0	0.069	0.133	<0.1	7.1	0.69	102	9.5
10/29/98	n/a	S0	10	1.050	1.320	0.186	0.268	<0.1	7.1	0.35	74	9.4
12/14/98	n/a	S0	<10	0.166	<1.0	0.033	0.036	1.100	6.5	10.2	29	3.9
02/09/99	n/a	S0	<5	0.110	<1.0	0.041	0.044	1.01(a)	6.2	10.7	24	5.5
04/02/99	9	S0	6	0.211	<1.0	0.051	.061(a)	0.861	6.3	6.9	30	7.4
04/22/99	9	S0	<5	0.115	<1.0	<.025	<.035	0.823	6.4	3.2	36	9.9
05/27/99	n/a	S0	<5	<0.1	<1.0	0.034	0.054	0.949	6.5	2.2	39	10.2
06/14/99	10	S0	<10	0.137	<1.0	0.056	0.077	0.738	7.4	2.8	40	10.2
06/30/99	10	S0	<5	0.164(a)	<1.0	0.039	0.053	0.681	6.7	2.4	83	10.2
07/08/99	11	S0	<10	0.144	<1.0	0.030	0.049	0.866	7.6	0.8	82	10.3
07/26/99	11	S0	<10	0.296	<1.0	0.040	0.064	0.392	7.1	0.5	83	10.5
08/12/99	12	S0	<5	0.274	<1.0	0.028	0.090	0.365	6.9	0.2	86	10.5
08/30/99	12	S0	5	0.649(a)	<1.0	0.113	0.235(a)	<0.1	6.4	0.4	110	10.4
09/15/99	13	S0	<10	0.168	<1.0	.067(a)	0.125	<0.1	6.6	0.3	112	10.5
09/29/99	13	S0	n/a(vr)	0.353(a)	<1.0(a)	n/a(vr)	0.191(a)	n/a(vr)	6.1	0.3	117	10.6
10/22/99	n/a	S1	12	0.900	1.180	0.114	0.187	<0.100	n/a	0.2	135	10.5
11/18/99	n/a	S1	5	0.197	<1.0	0.048	0.068	0.635	n/a	1.4	111	10.3
12/22/99	n/a	S1	<10	<0.1	0.880	0.027	0.029	1.040	n/a	9.2	49	7.5
01/26/00	n/a	S1	<5	<0.05	<0.5	0.015	0.018	1.010	n/a	10.6	49	5.1
02/28/00	n/a	S1	<5	<0.05	0.517	0.010	0.022	0.984	n/a	9.8	57	6.5
03/23/00	n/a	S1	<5	0.127	0.588	0.009	0.033	0.740	n/a	7.1	62	7.2
04/18/00	n/a	S1	<5	0.103	0.882	0.012	0.037	0.858	n/a	4.3	67	7.7
05/16/00	n/a	S1	<5	<0.05	0.442	0.009	0.047	0.891	n/a	3.9	67	8
06/19/00	n/a	S1	<5	0.061	0.629	0.006	0.048	0.573	n/a	2.6	70	8.5
07/12/00	n/a	S1	<5	0.158	0.751	0.006	0.031	0.342	n/a	0.5	73	8.9
08/15/00	n/a	S1	<5	0.122	0.485	<0.005	0.052	0.278	n/a	2	84	9.2
09/13/00	n/a	S1	<4	0.422	0.978	0.142	0.128	0.030(a)	n/a	0.3	102	9.1
10/23/00	n/a	S2	8	0.350	1.080	<0.010	0.055	0.024	n/a	0.7	114	9.3
11/01/00	n/a	S2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
12/07/00	n/a	S2	4	0.098	<0.500	0.008	0.033	0.590	n/a	10.0	83	5.4
01/16/01	n/a	S2	<5	<0.050	0.565	0.019	0.022	1.030	n/a	10.7	71	5.1
02/21/01	n/a	S2	<5	<0.050	<0.500	0.013	0.022	1.260	n/a	11.8	69	5.2
03/20/01	n/a	S2	4	<0.050	0.522	0.017	0.028	1.410	n/a	8.8	72	6.6
04/25/01	n/a	S2	4	<0.050	0.575	0.028	0.032	1.700	n/a	4.3	69	7.3
05/24/01	n/a	S2	2	<0.050	0.544	0.008	0.038	0.491	n/a	2.0	72	7.7
06/20/01	n/a	S2	<2	0.099	0.732	0.020	0.029	0.661	n/a	0.6	73	8.0
07/11/01	n/a	S2	<1.9	0.141	0.620	0.008	0.018	0.537	n/a	0.2	78	8.0
08/21/01	n/a	S2	3	0.253	<0.500	0.011	0.025	0.128	n/a	0.5	n/a(vr)	8.2
09/17/01	n/a	S2	6	0.607	1.190	0.125	0.143	0.010	n/a	0.22	113	8.3

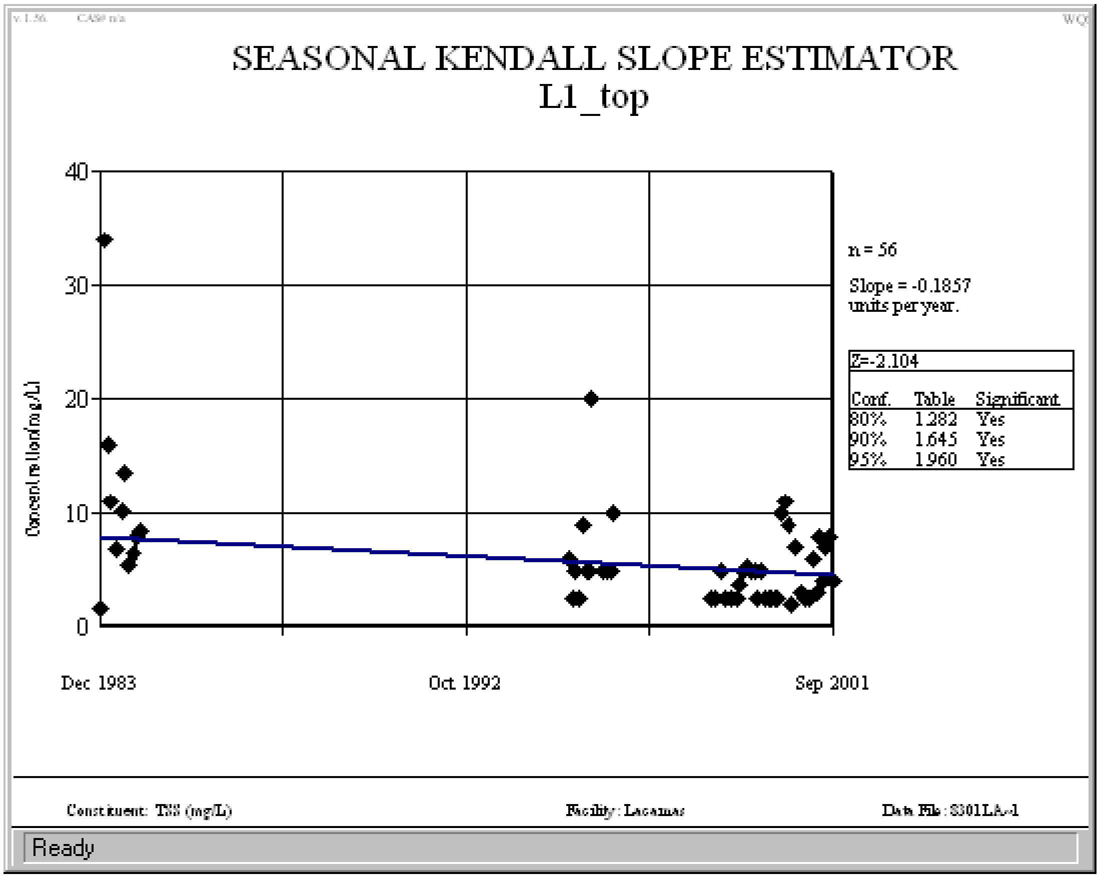
Flags and Notes pertaining to WQStat Plus database:

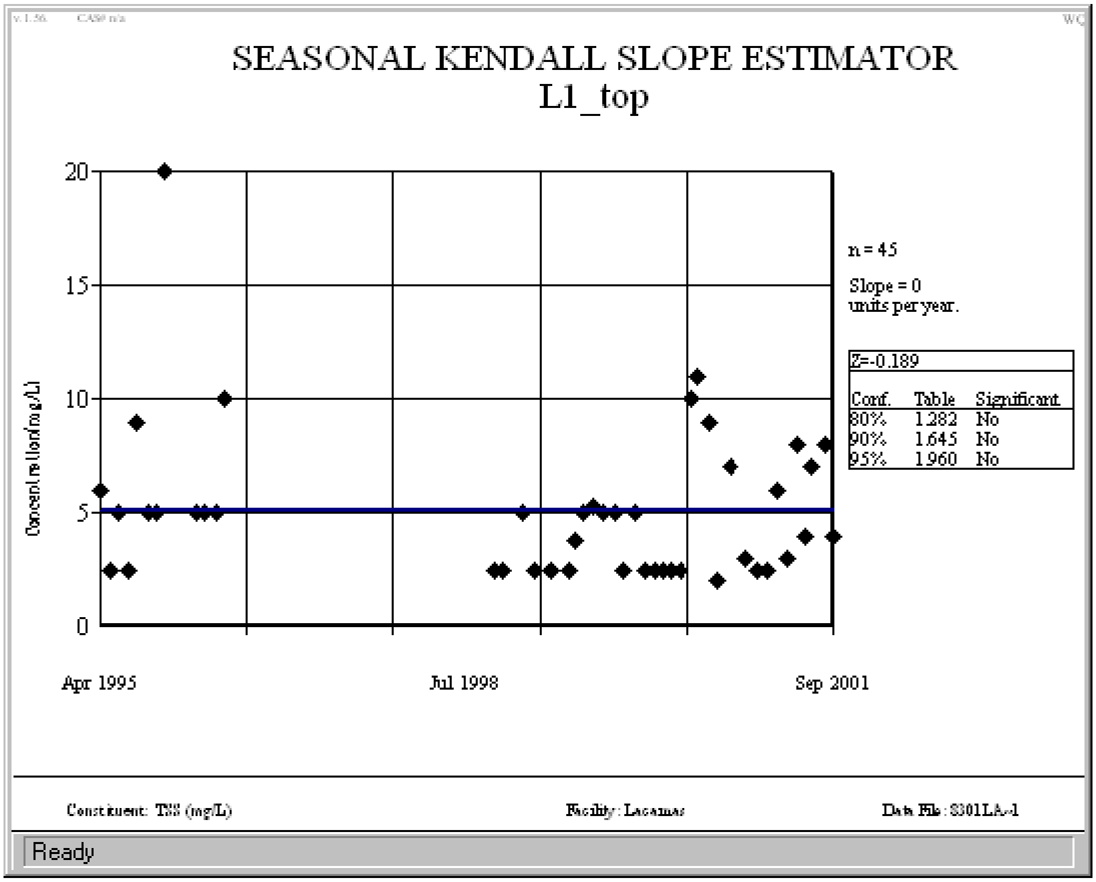
s	Substitution. Laboratory duplicate value substituted for original
a	Average. Laboratory duplicate value and original value averaged
k	Kept. Large difference between original and laboratory duplicate. Original value kept.
vr	Value Rejected. Value not included due to probable contamination, field error, etc.
R5	Data obtained from 1985 Diagnostic and Restoration Analysis Appendices.
L4	Data obtained from Jeff Lafer 1994 report.
LS	Data obtained from Jeff Lafer spreadsheets L19394pc.xls and L1TDO914.xls.
E5	Data obtained from 1995 E&S Environmental Chemistry report.
E6	Data obtained from 1996 E&S Environmental Chemistry report.
SO	Data obtained from Jeff Schnabel 1998-99 database (9899inlake.xls, profiledata.xls), 2000 report
S1	Data obtained from Jeff Schnabel 1999-2000 database (9900inlake.xls, 9900profiledata.xls), 2001 report
S2	Data obtained from Jeff Schnabel WY2001 database (wy2001inlake.xls, wy2001profiledata.xls)

1983-84 values: Top = 1m value for vertical profiles
Bot = 17m value for vertical profiles
(to match 1998-99 sampling depths)

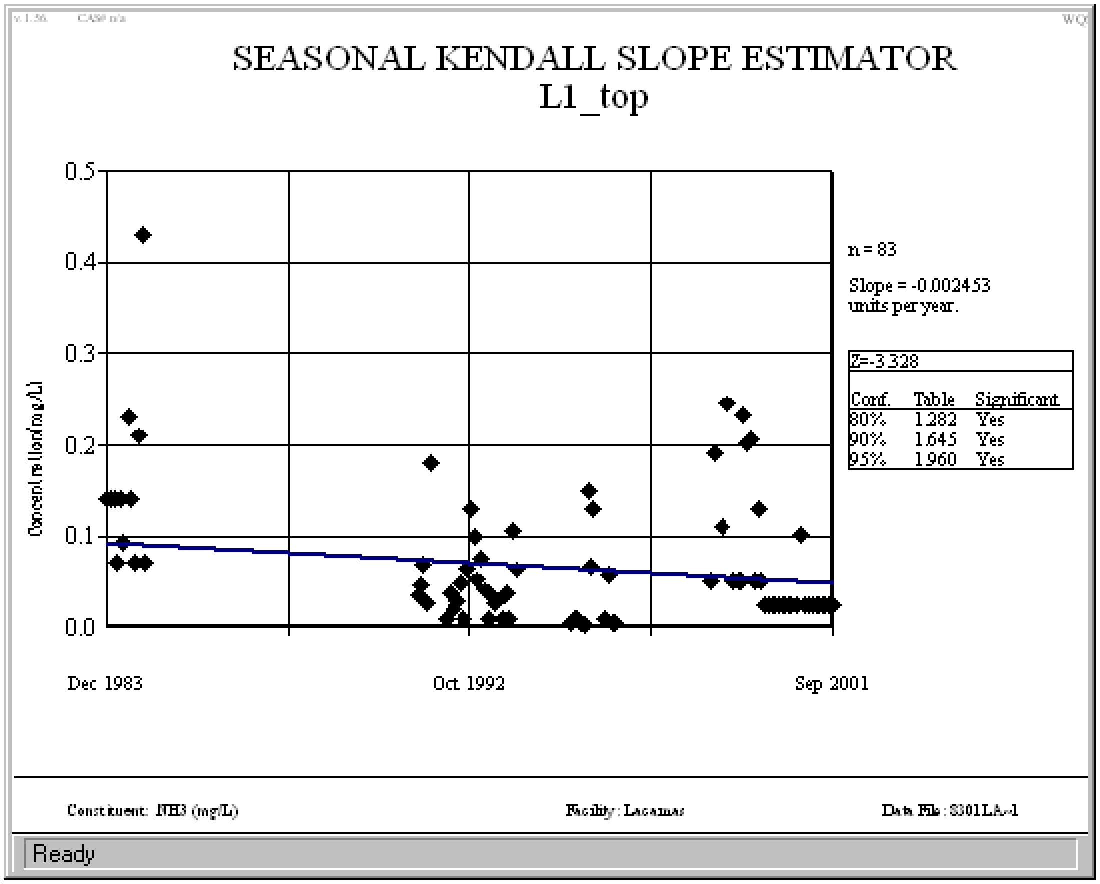
1991-92 values: Top = 1m value for vertical profiles
Bot = 55' value or deepest point measured for vertical profiles
(to match 1998-99 sampling depths)

Appendix 7: Seasonal Kendall trend tests, Lacamas Lake epilimnion, 1983-2001 and 1991-2001.

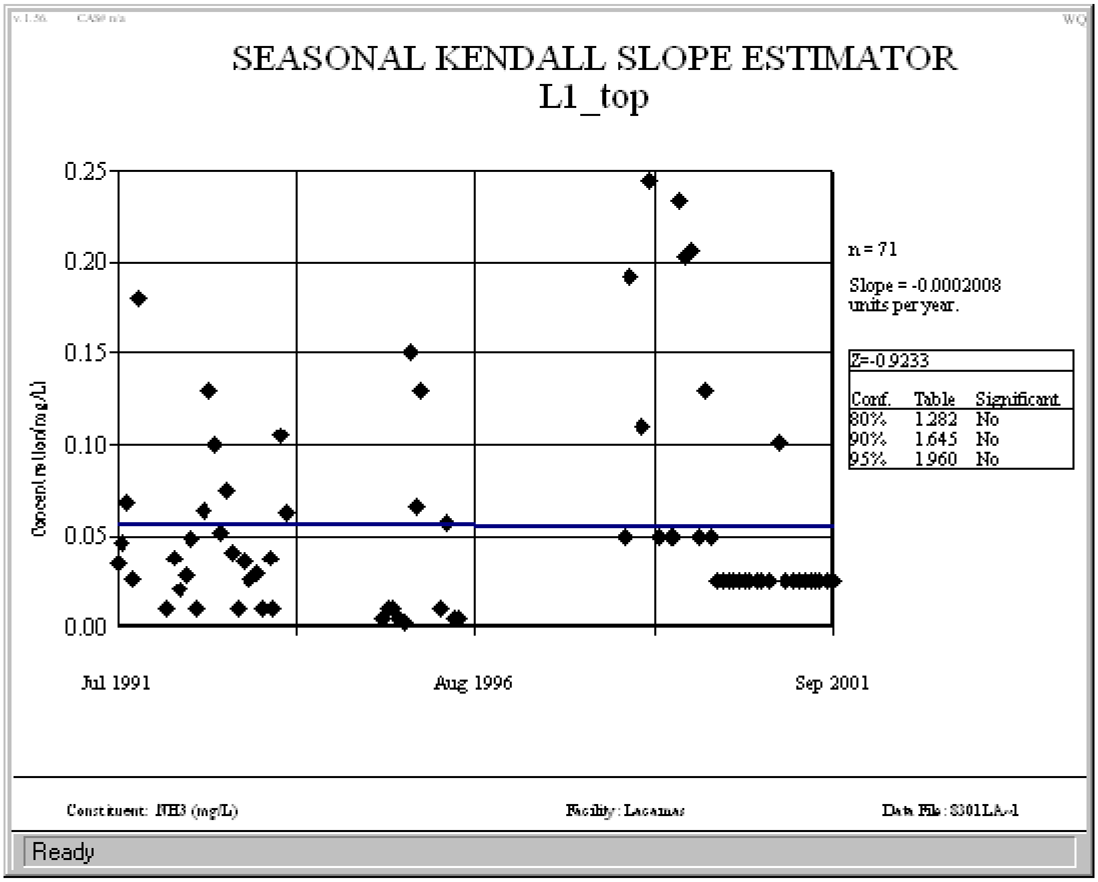




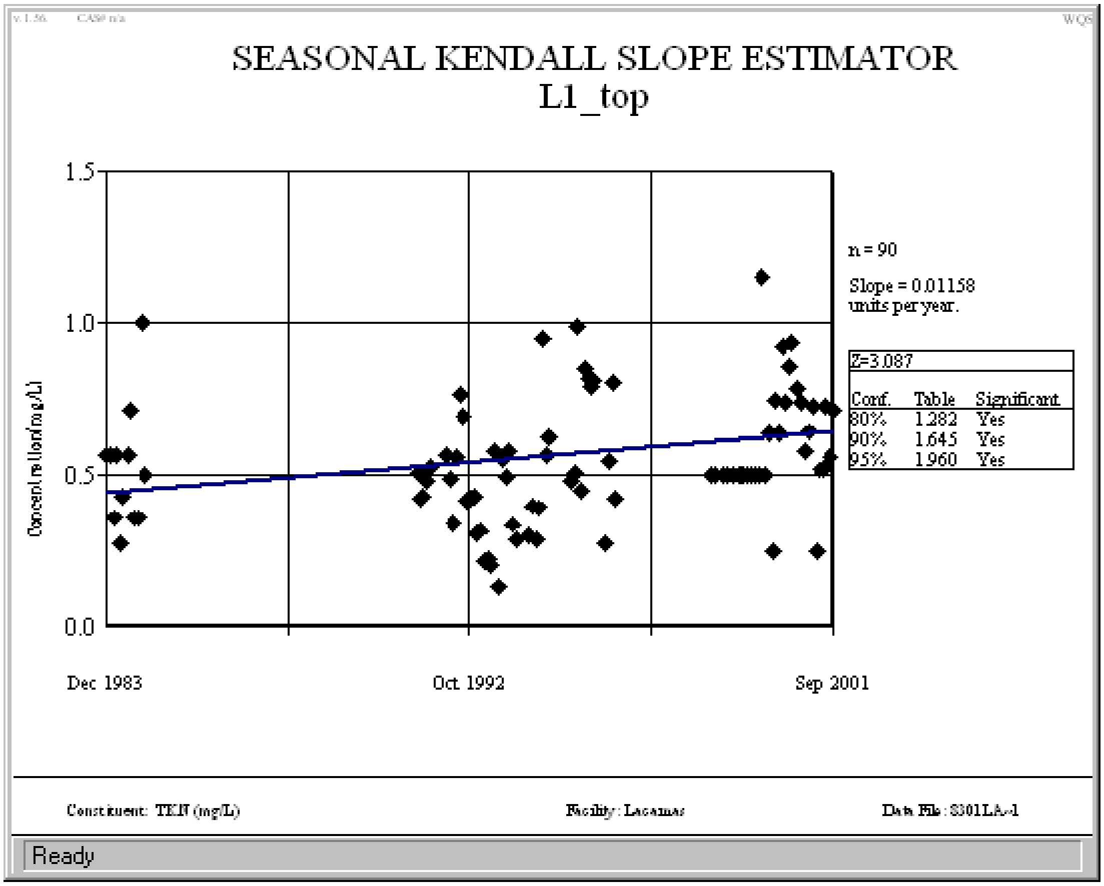
SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
Concentration (mg/L)
20
15
10
5
0
Apr 1995
Jul 1998
Sep 2001
n = 45
Slope = 0
units per year.
Z=-0.189
Conf. Table Significant
80% 1.282 No
90% 1.645 No
95% 1.960 No
Constituent: TSS (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready

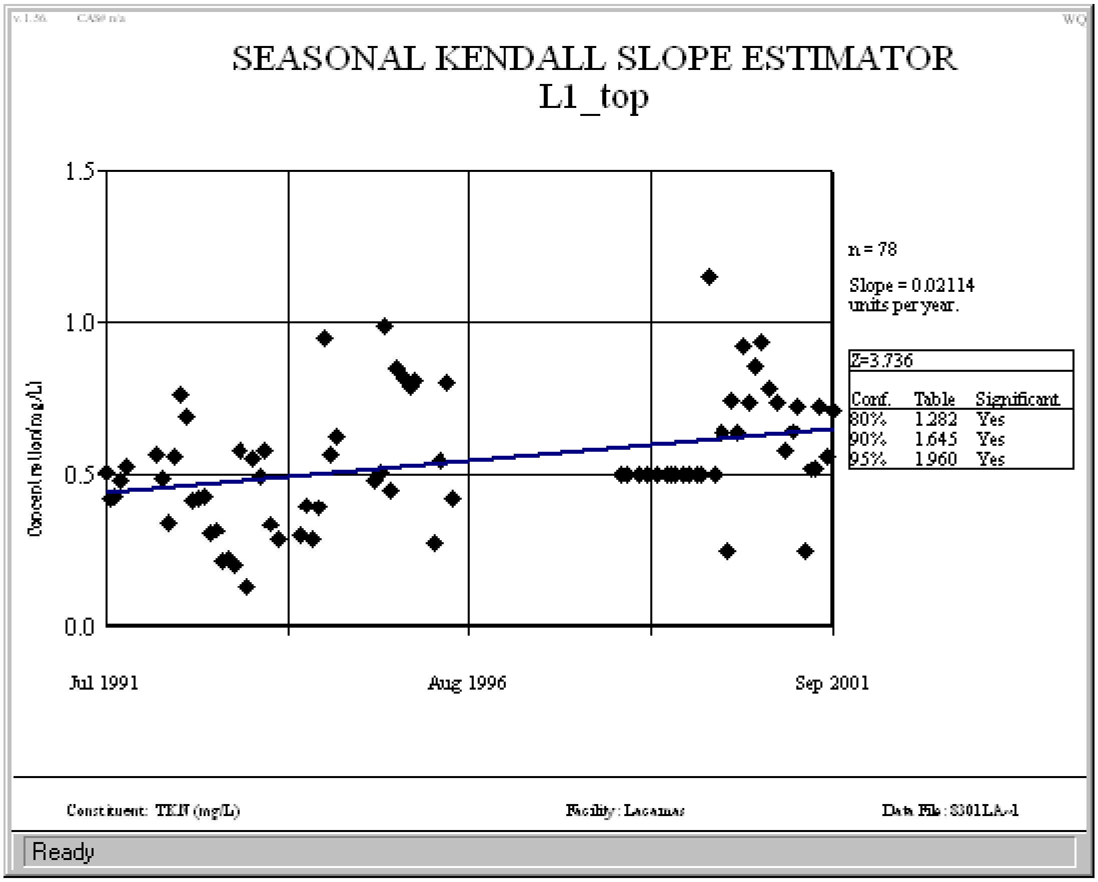


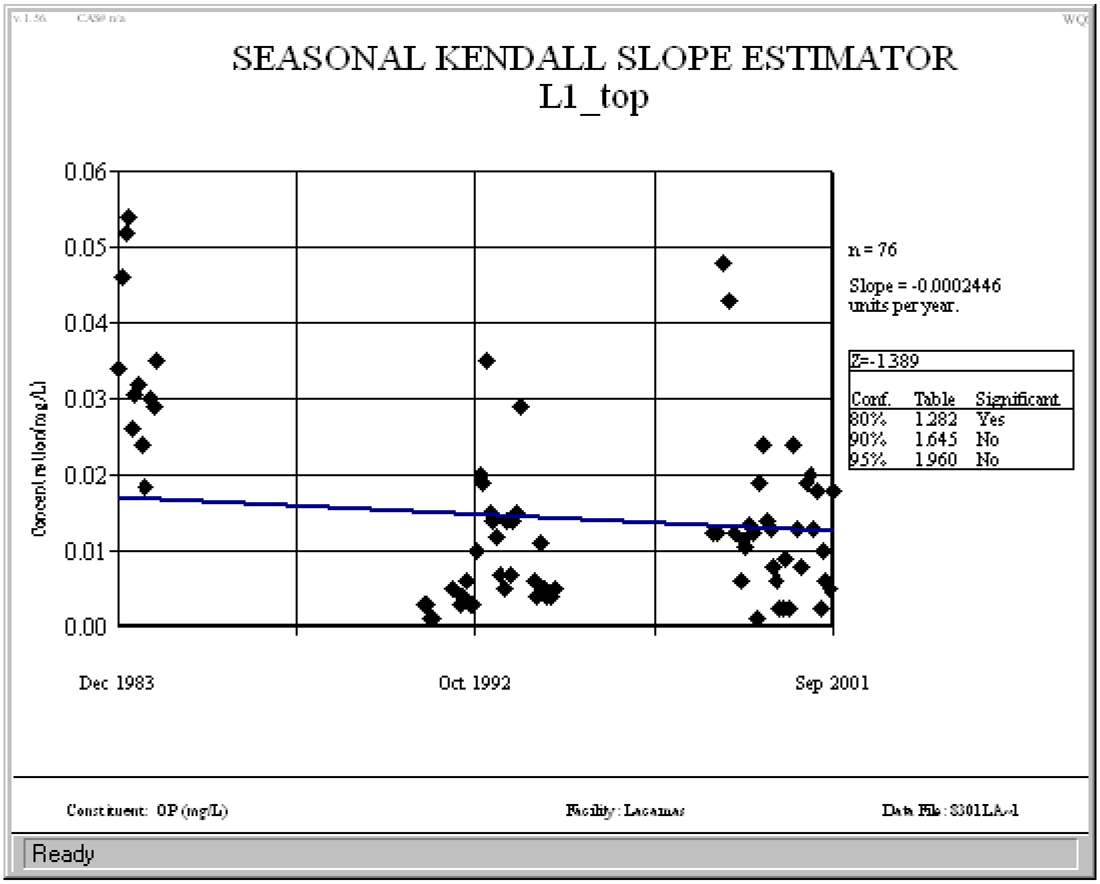
SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
Concentration (mg/L)
0.5
0.4
0.3
0.2
0.1
0.0
Dec 1983
Oct 1992
Sep 2001
n = 83
Slope = -0.002453 units per year.
Z=-3.328
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 Yes
Constituent: NH3 (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready

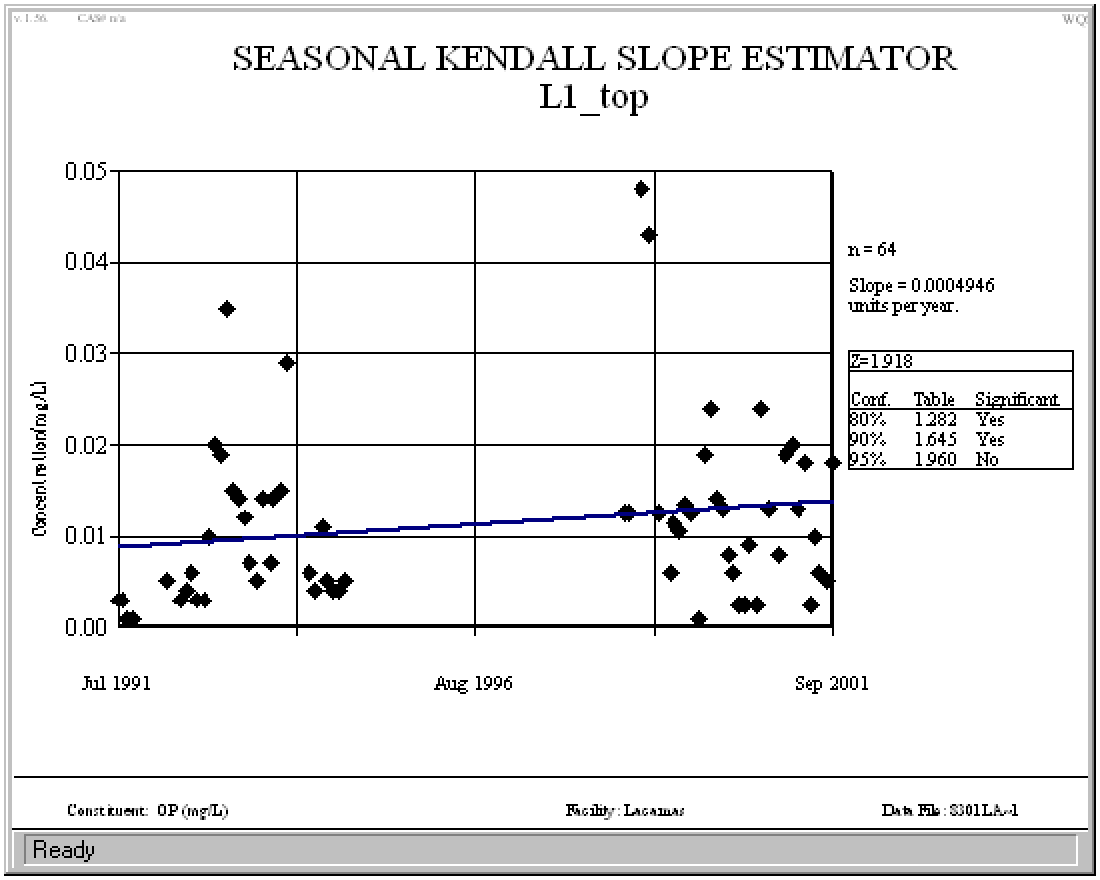


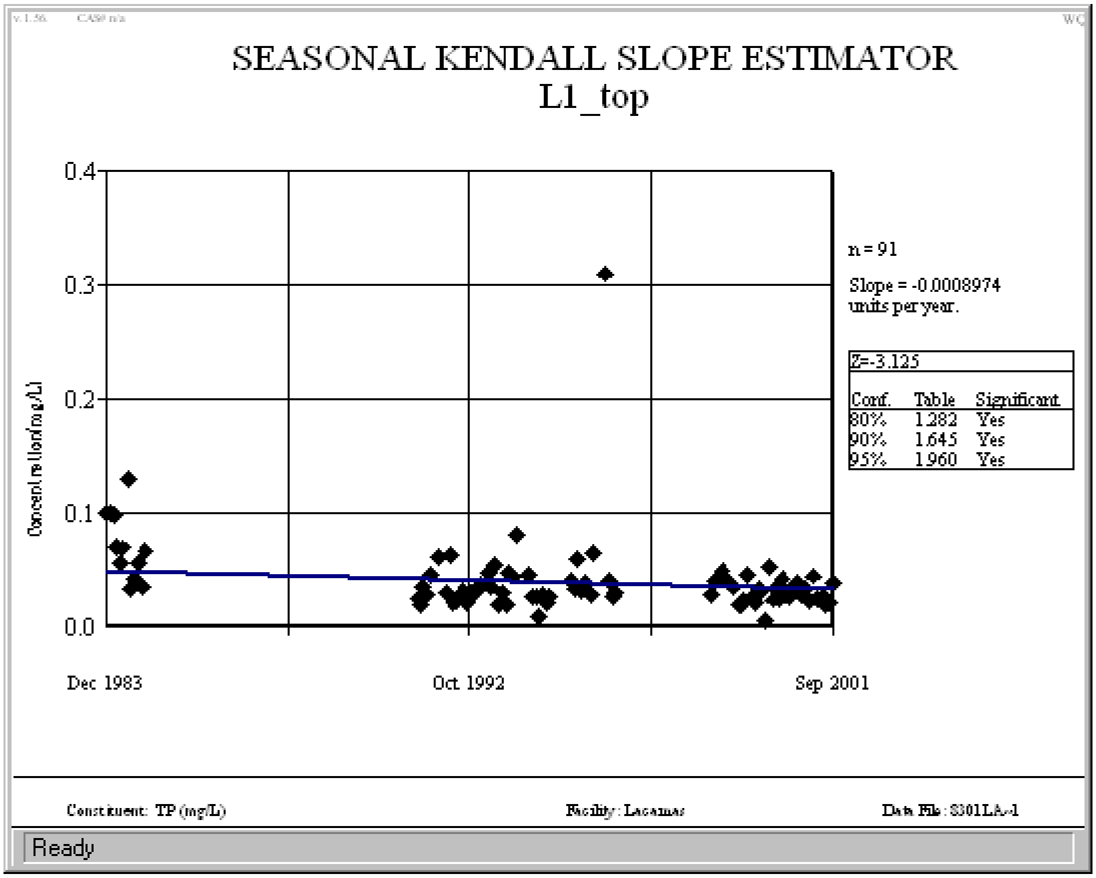
v. 1.56
CAS# n/a
WQ
SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
0.25
0.20
0.15
0.10
0.05
0.00
Concentration (mg/L)
Jul 1991
Aug 1996
Sep 2001
n = 71
Slope = -0.0002008
units per year.
Z=-0.9233
Conf. Table Significant
80% 1.282 No
90% 1.645 No
95% 1.960 No
Constituent: NH3 (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready

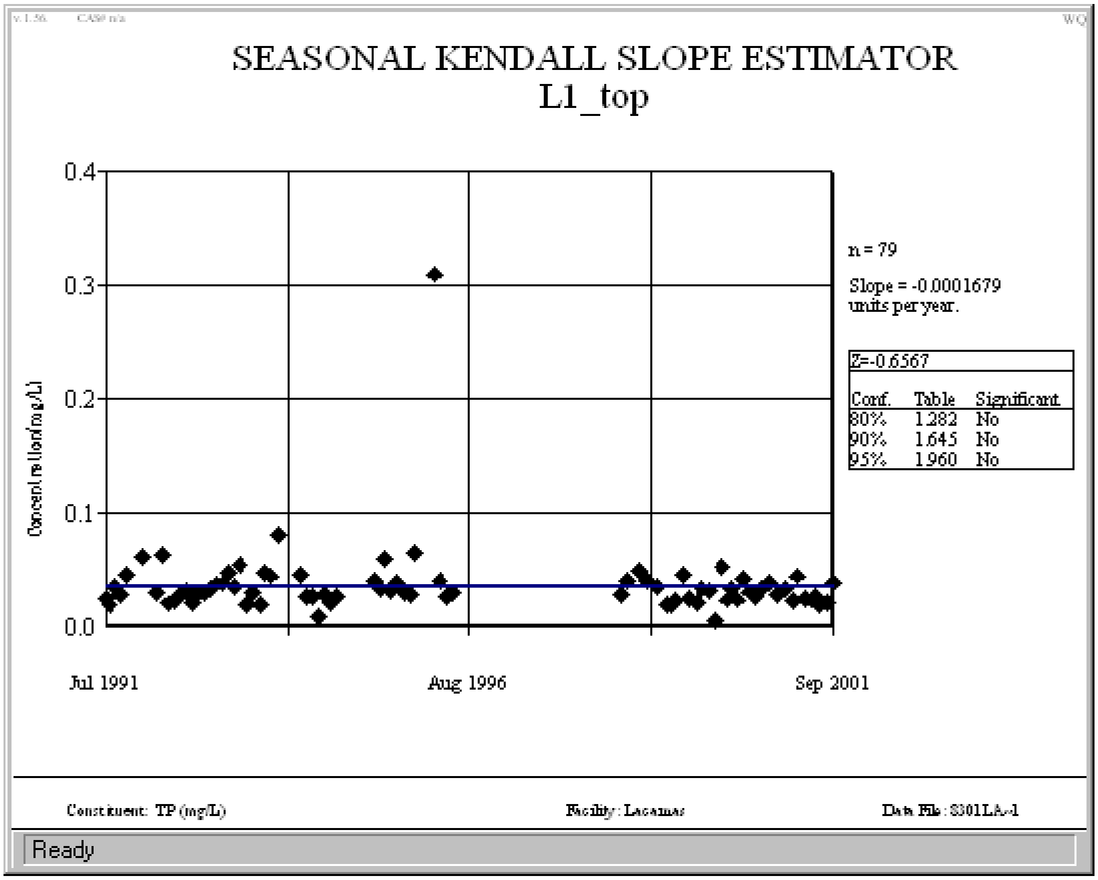

v.1.56 CAS# n/a
WQS
SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
1.5
1.0
0.5
0.0
Concentration (mg/L)
n = 90
Slope = 0.01158
units per year.
Z=3.087
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 Yes
Dec 1983
Oct 1992
Sep 2001
Constituent: TKN (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready

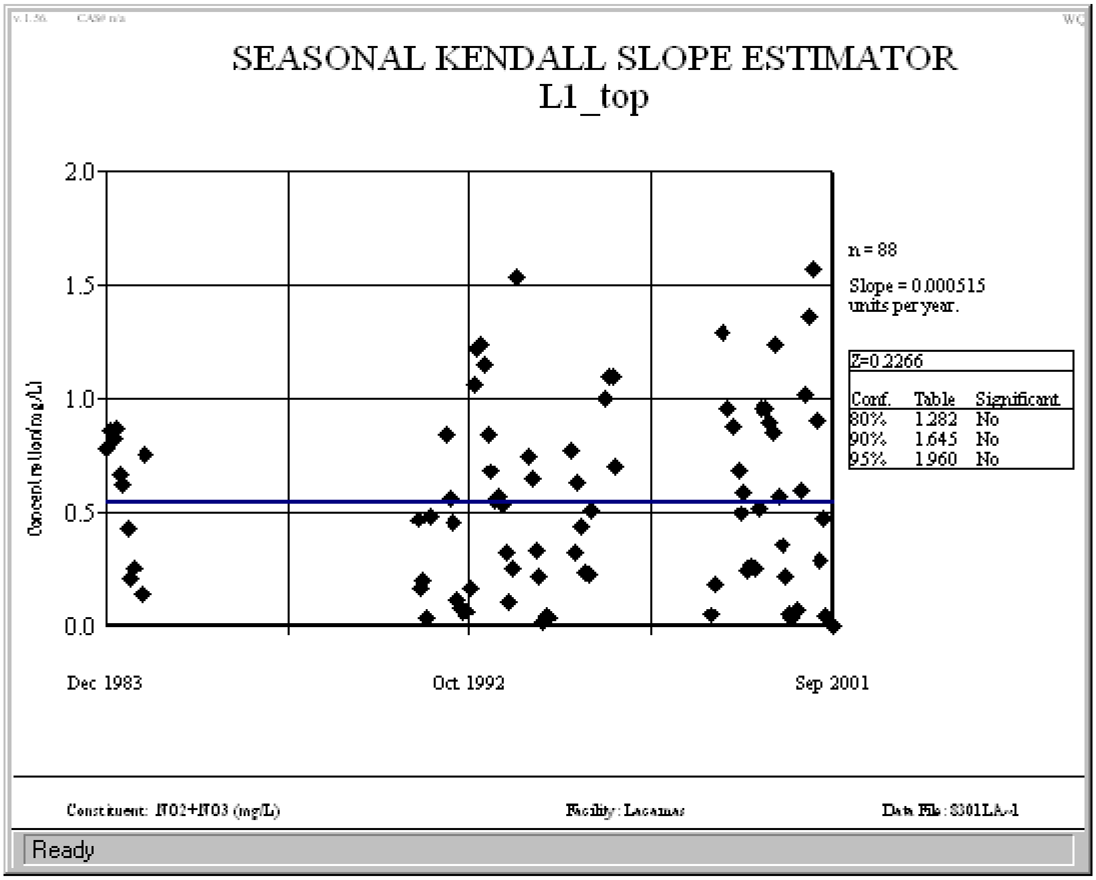

v. 1.56
CAS# n/a
WQ
SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
1.5
1.0
0.5
0.0
Concentration (mg/L)
Jul 1991
Aug 1996
Sep 2001
n = 78
Slope = 0.02114
units per year.
Z=3.736
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 Yes
Constituent: TKN (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready

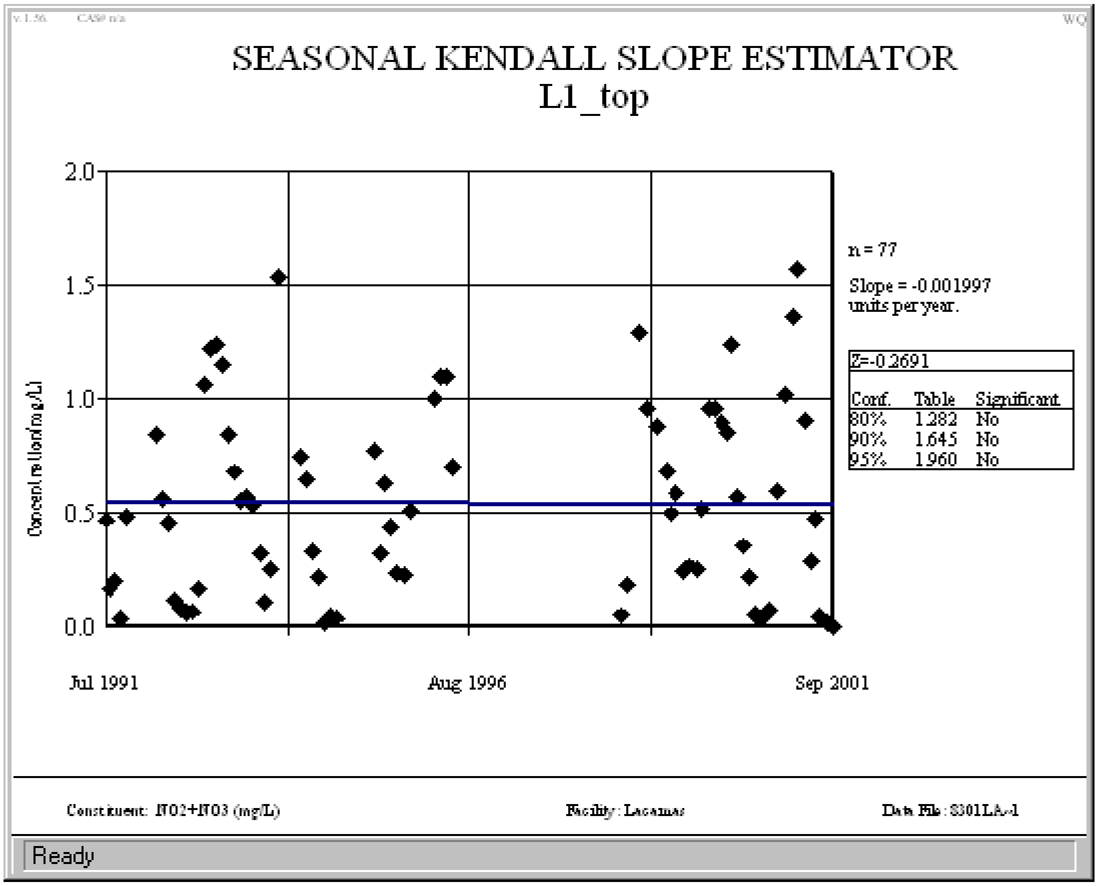

v.1.56 CAS# n/a
WQ
SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Concentration (mg/L)
Dec 1983
Oct 1992
Sep 2001
n = 76
Slope = -0.0002446
units per year.
Z=-1.389
Conf. Table Significant
80% 1.282 Yes
90% 1.645 No
95% 1.960 No
Constituent: OP (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready


SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
0.05
0.04
0.03
0.02
0.01
0.00
Concentration (mg/L)
Jul 1991
Aug 1996
Sep 2001
n = 64
Slope = 0.0004946
units per year.
Z=1.918
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 No
Constituent: OP (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready

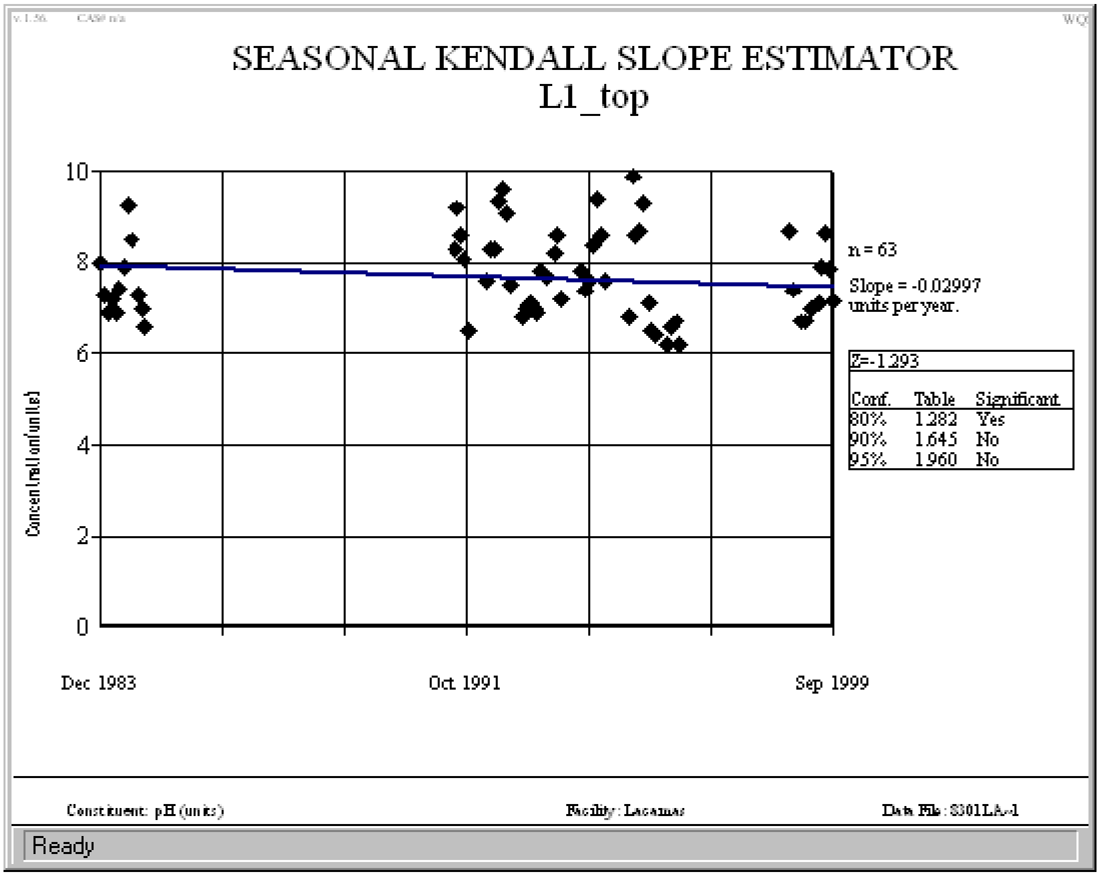

SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
0.4
0.3
0.2
0.1
0.0
Concentration (mg/L)
n = 91
Slope = -0.0008974
units per year.
Z=-3.125
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 Yes
Dec 1983
Oct 1992
Sep 2001
Constituent: TP (mg/L)
Facility: Lacamas
Ready

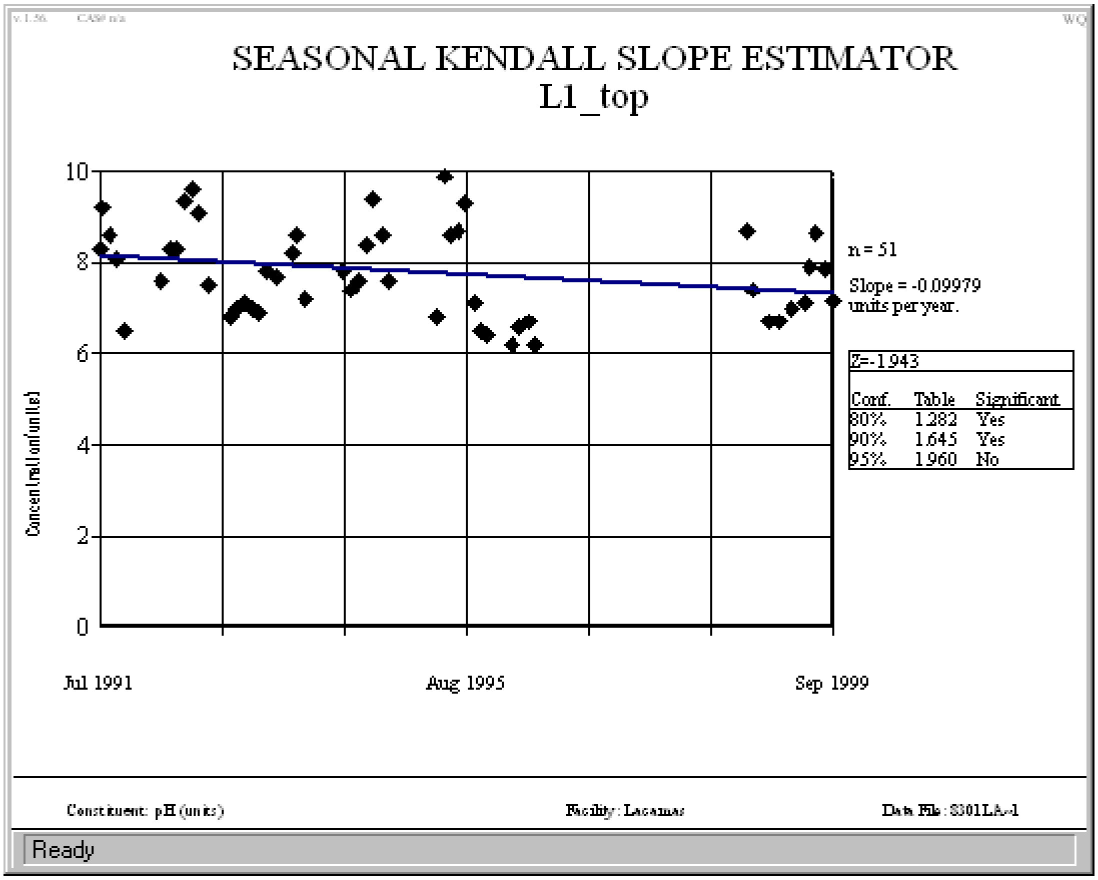

SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
0.4
0.3
0.2
0.1
0.0
Concentration (mg/L)
n = 79
Slope = -0.0001679
units per year.
Z=-0.6567
Conf. Table Significant
80% 1.282 No
90% 1.645 No
95% 1.960 No
Jul 1991
Aug 1996
Sep 2001
Constituent: TP (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready

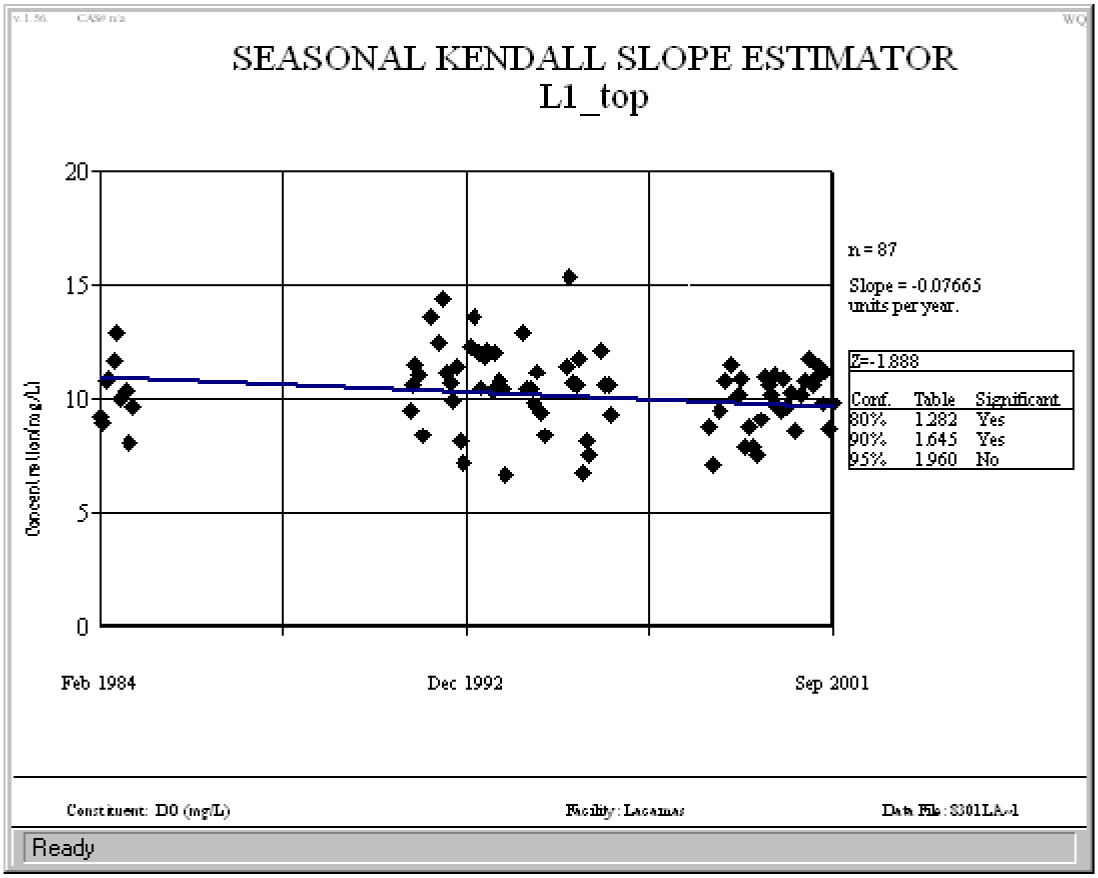

SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
2.0
1.5
1.0
0.5
0.0
Concentration (mg/L)
Dec 1983
Oct 1992
Sep 2001
n = 88
Slope = 0.000515
units per year.
Z=0.2266
Conf. Table Significant
80% 1.282 No
90% 1.645 No
95% 1.960 No
Constituent: NO2+NO3 (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready

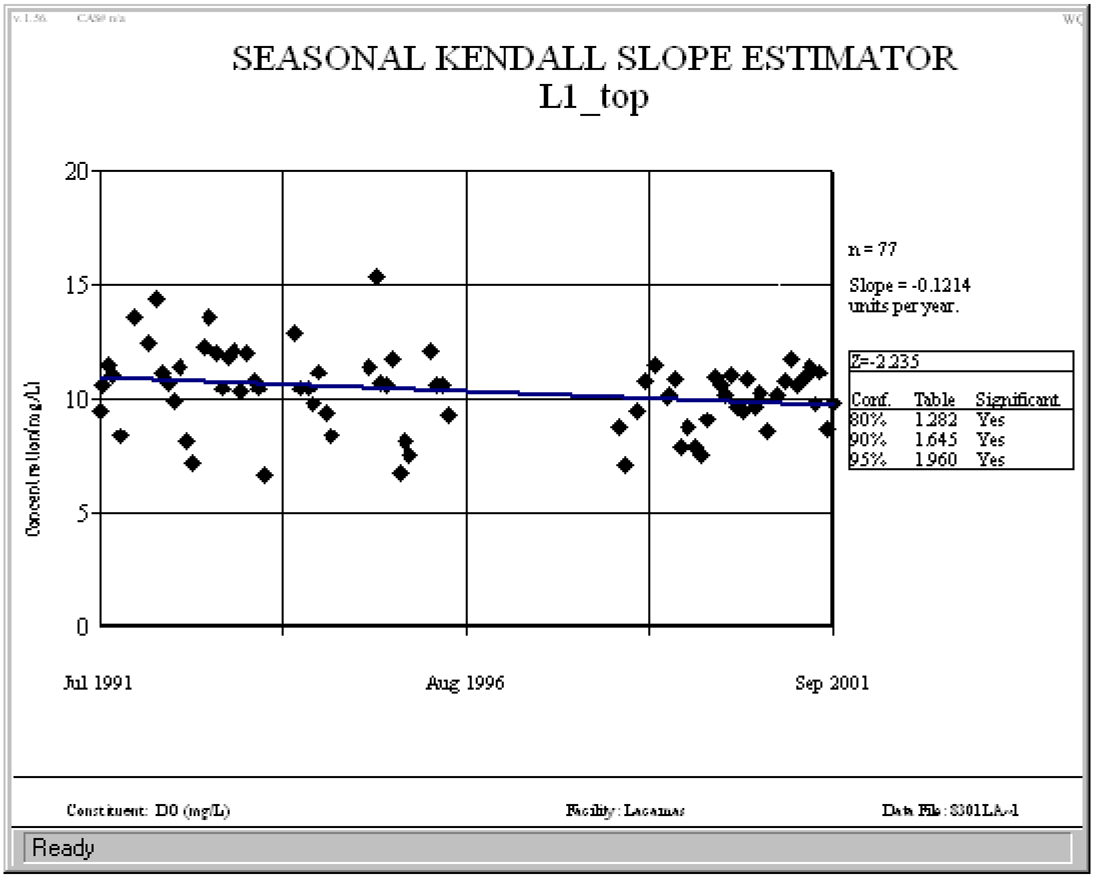


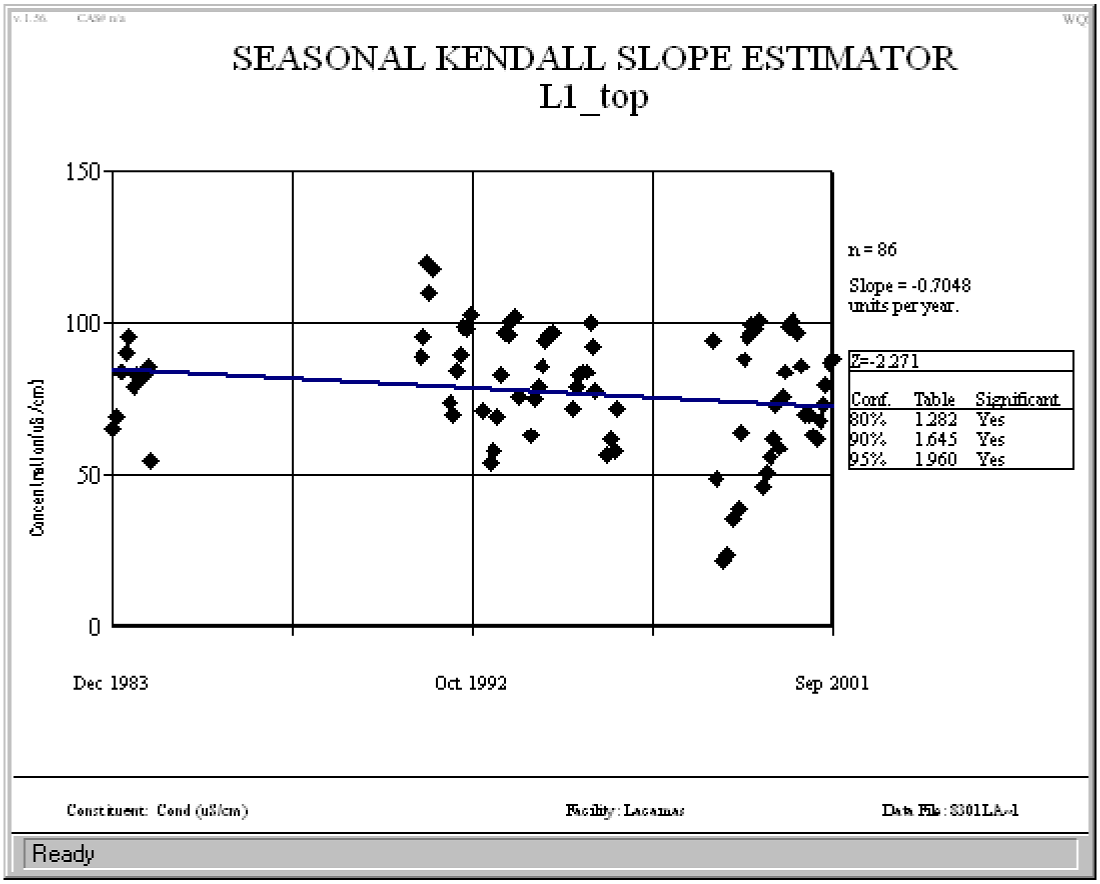
v.1.56
CAS# n/a
WQ
SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
2.0
1.5
1.0
0.5
0.0
Concentration (mg/L)
Jul 1991
Aug 1996
Sep 2001
n = 77
Slope = -0.001997
units per year.
Z=-0.2691
Conf. Table Significant
80% 1.282 No
90% 1.645 No
95% 1.960 No
Constituent: NO2+NO3 (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready

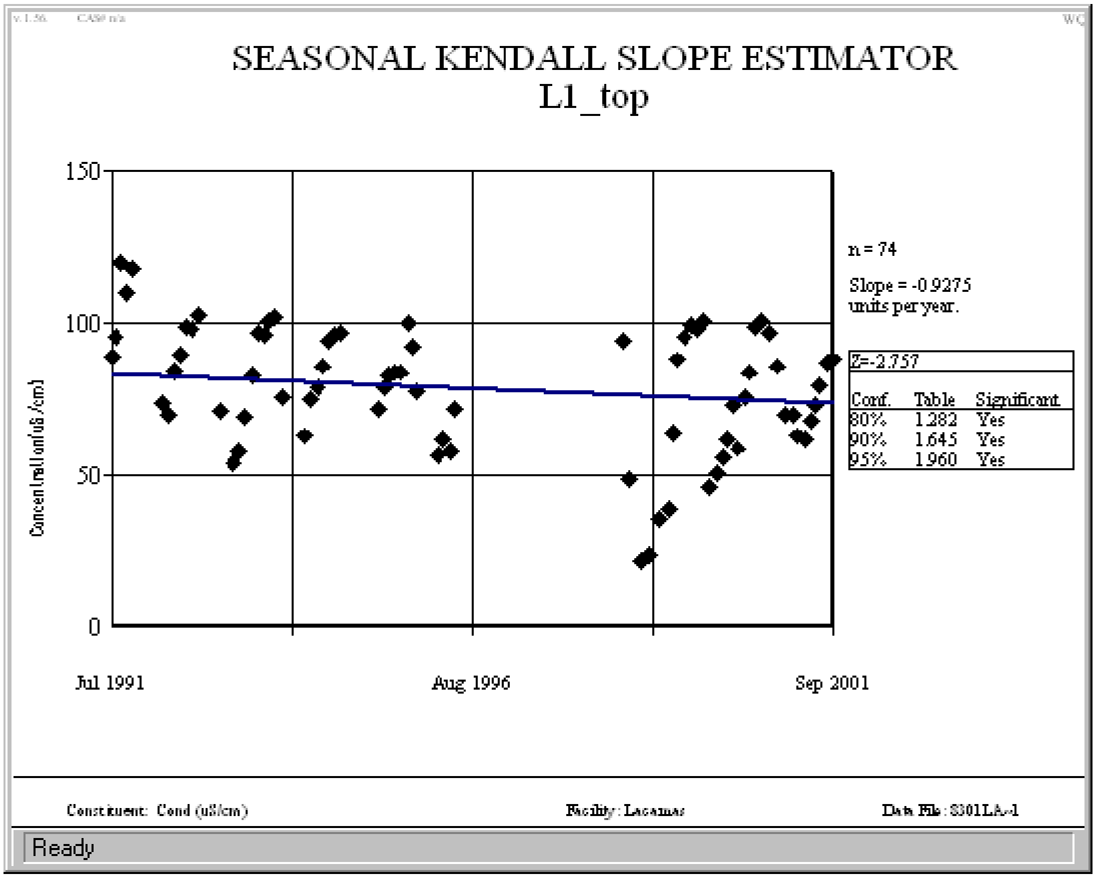

SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
10
8
6
4
2
0
Concen (mg/l or units)
Dec 1983
Oct 1991
Sep 1999
n = 63
Slope = -0.02997 units per year.
Z=-1.293
Conf. Table Significant
80% 1.282 Yes
90% 1.645 No
95% 1.960 No
Constituent: pH (units)
Facility: Lacamas
Data File: S301LA-1
Ready


SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
n = 51
Slope = -0.09979
units per year.
Z=-1.943
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 No
Jul 1991
Aug 1995
Sep 1999
Constituent: pH (units)
Facility: Lacamas
Data File: S301LA-1
Ready

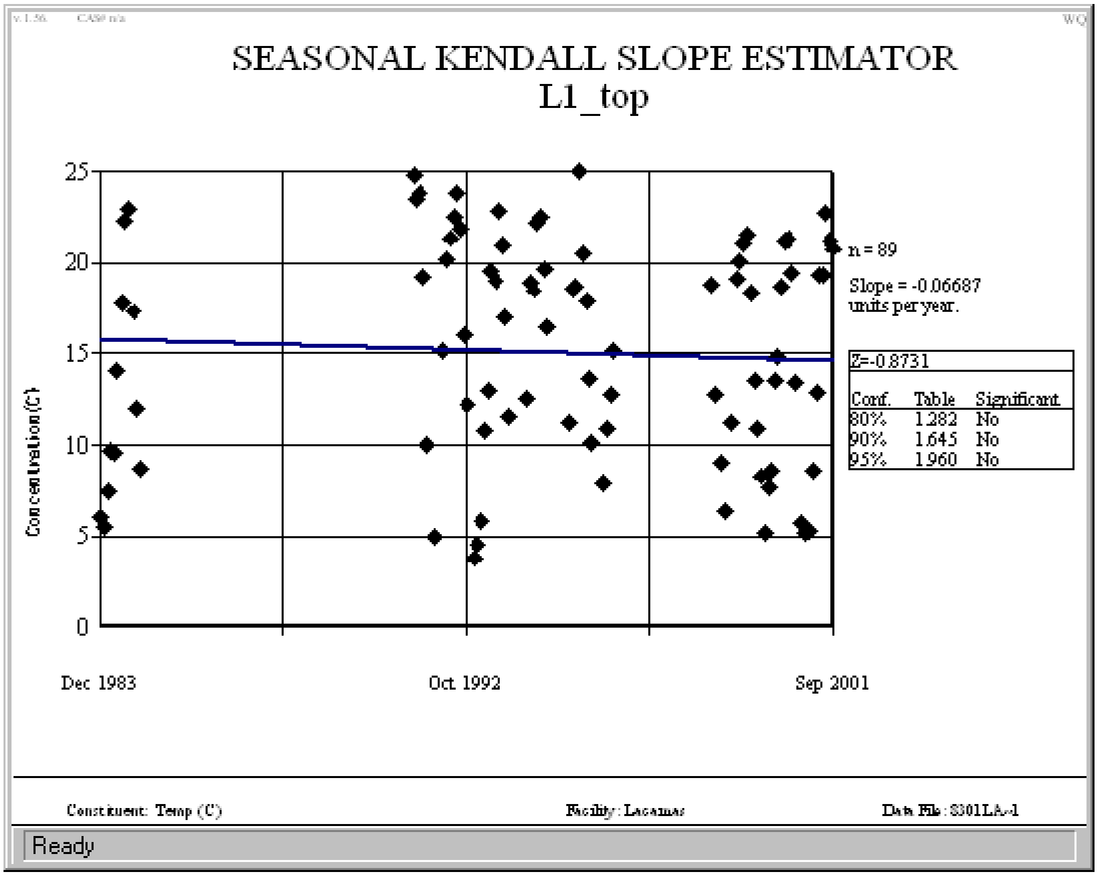

v.1.56. CAS# n/a
WQ
SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
20
15
10
5
0
Concentration (mg/L)
Feb 1984
Dec 1992
Sep 2001
n = 87
Slope = -0.07665
units per year.
Z=-1.888
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 No
Constituent: DO (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready


SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
20
15
10
5
0
Concentration (mg/L)
Jul 1991
Aug 1996
Sep 2001
n = 77
Slope = -0.1214
units per year.
Z=-2.235
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 Yes
Constituent: DO (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready


SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
150
100
50
0
Dec 1983
Oct 1992
Sep 2001
n = 86
Slope = -0.7048
units per year.
Z=-2.271
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 Yes
Constituent: Cond (uS/cm)
Facility: Lacamas
Data File: S301LA-1
Ready



SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
150
100
50
0
Concentration (uS/cm)
Jul 1991
Aug 1996
Sep 2001
n = 74
Slope = -0.9275
units per year.
Z=-2.757
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 Yes
Constituent: Cond (uS/cm)
Facility: Lacamas
Data File: S301LA-1
Ready


v.1.56 CAS# n/a
WQ
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L1_top
25
20
15
10
5
0
Concentration (C)
Dec 1983
Oct 1992
Sep 2001
n = 89
Slope = -0.06687
units per year.
Z=-0.8731
Conf. Table Significant
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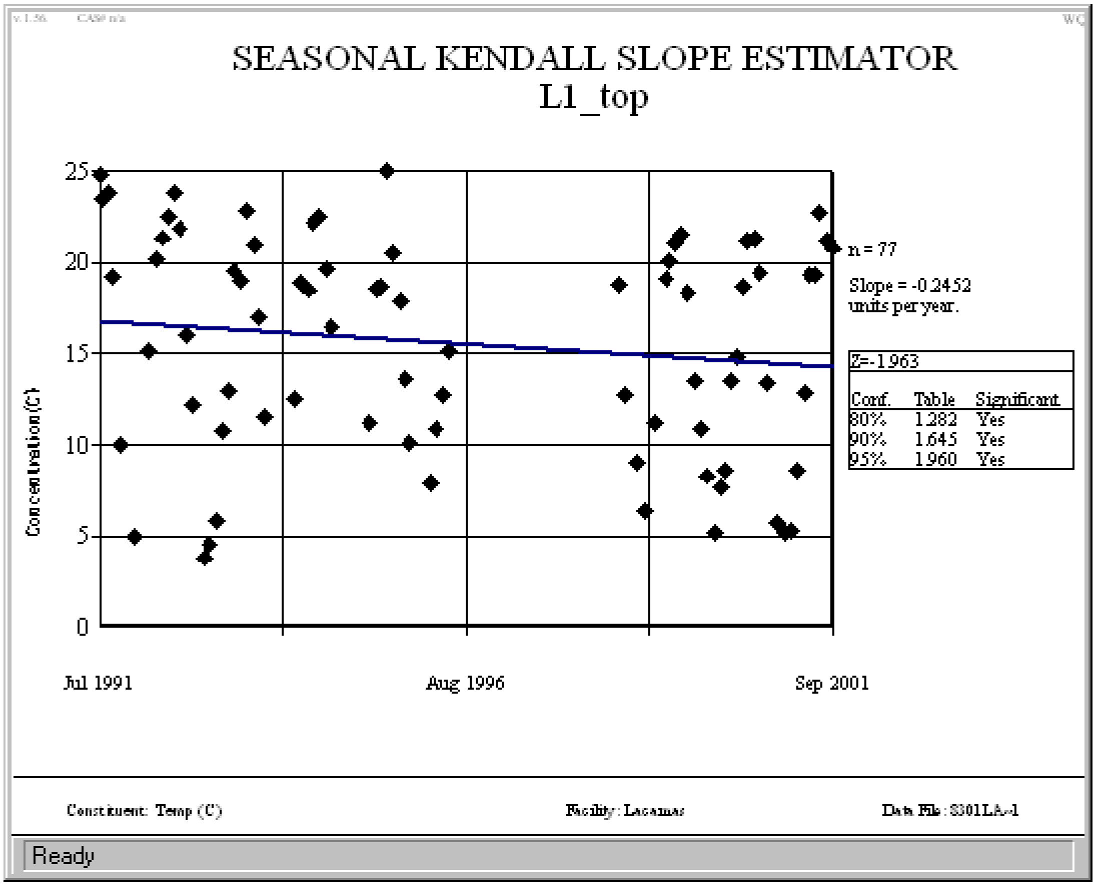
90% 1.645 No
95% 1.960 No
Constituent: Temp (C)
Facility: Lacamas
Data File: S301LA-1
Ready


v.1.56.
CAS# n/a
WQ
SEASONAL KENDALL SLOPE ESTIMATOR
L1_top
Concentration (C)
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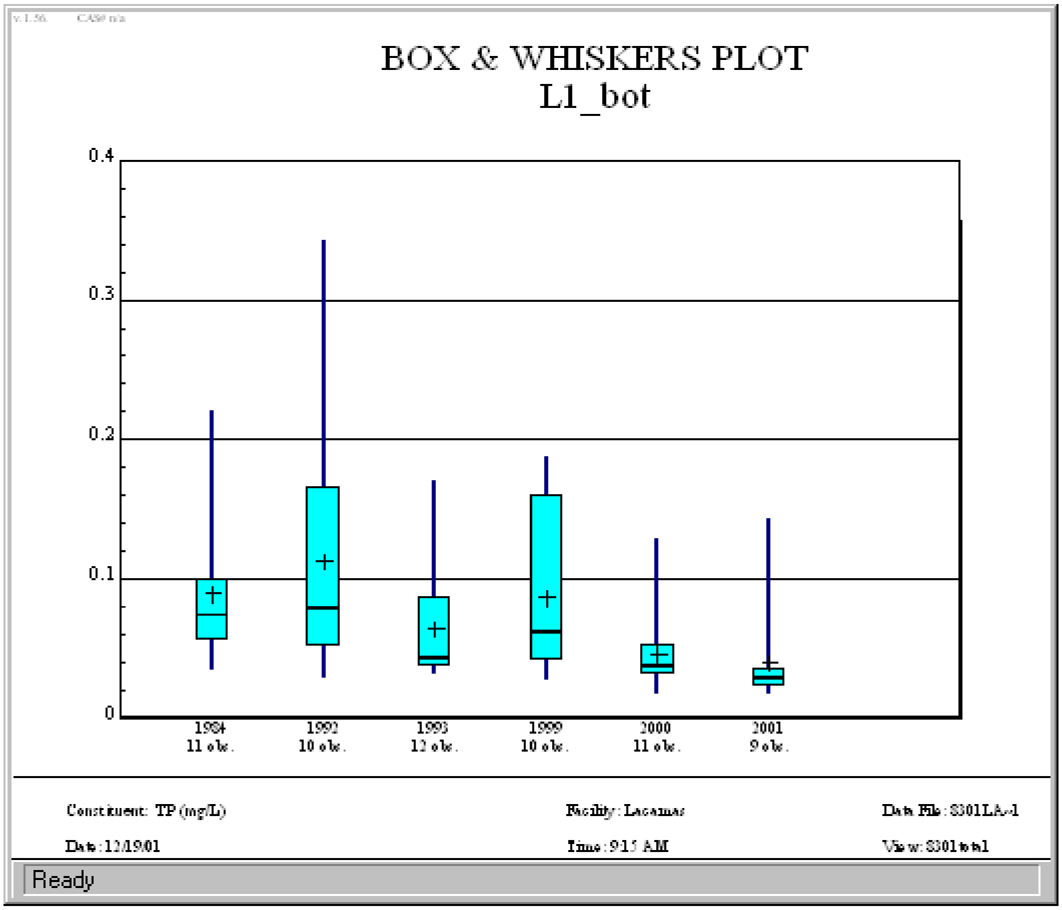
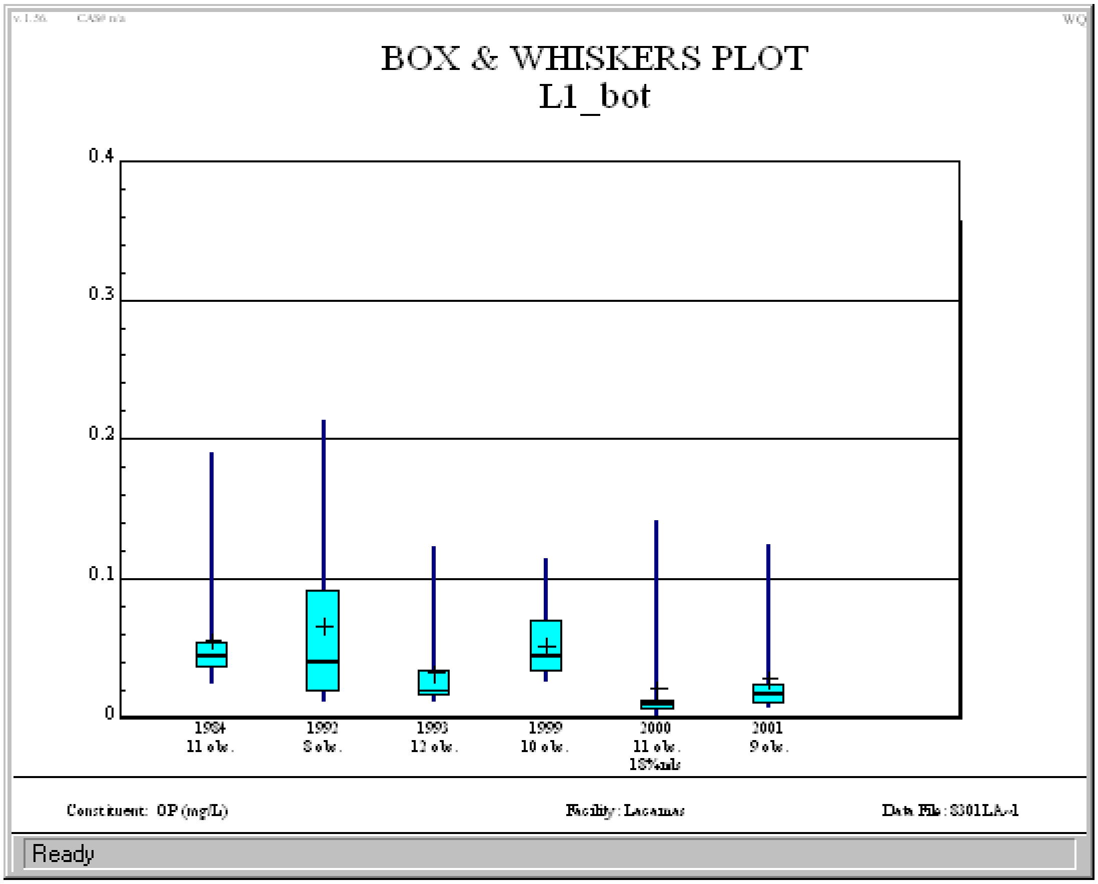
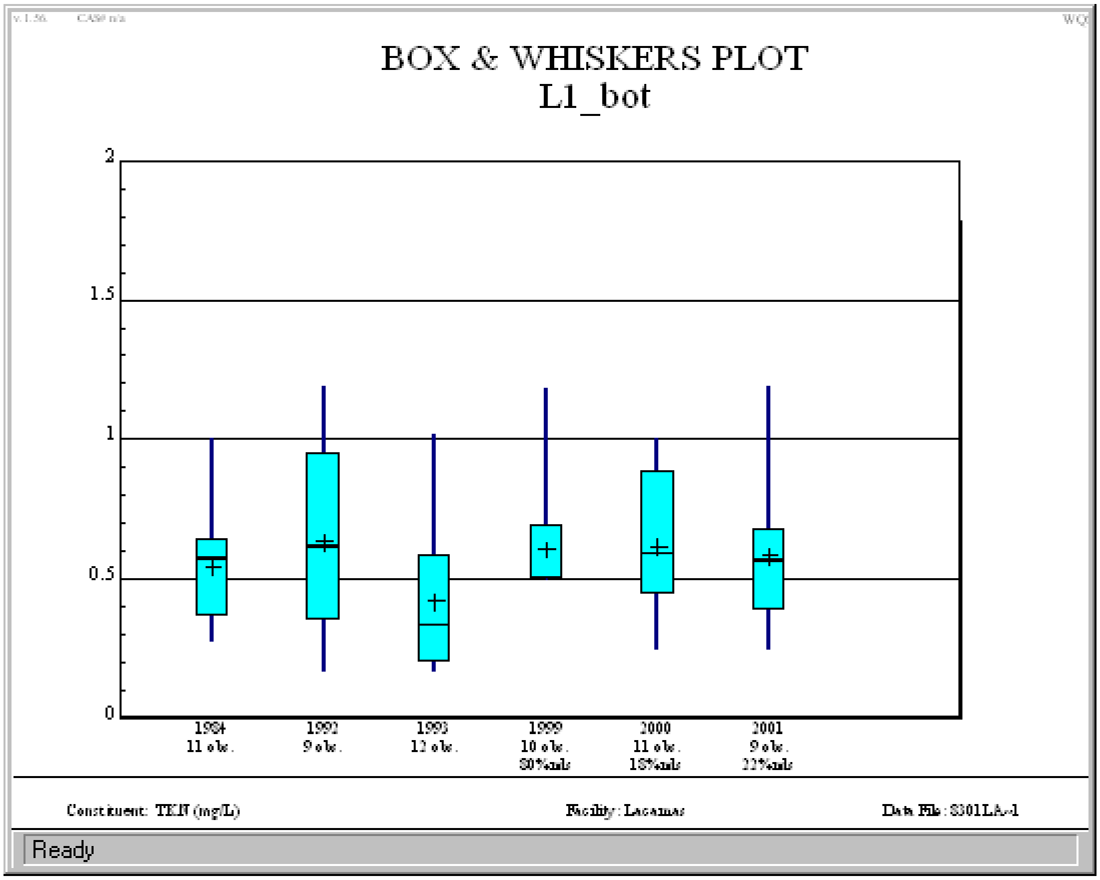
20
15
10
5
0
Jul 1991
Aug 1996
Sep 2001
n = 77
Slope = -0.2452
units per year.
Z=-1.963
Conf. Table Significant
80% 1.282 Yes
90% 1.645 Yes
95% 1.960 Yes
Constituent: Temp (C)
Facility: Lacamas
Data File: S301LA-1
Ready

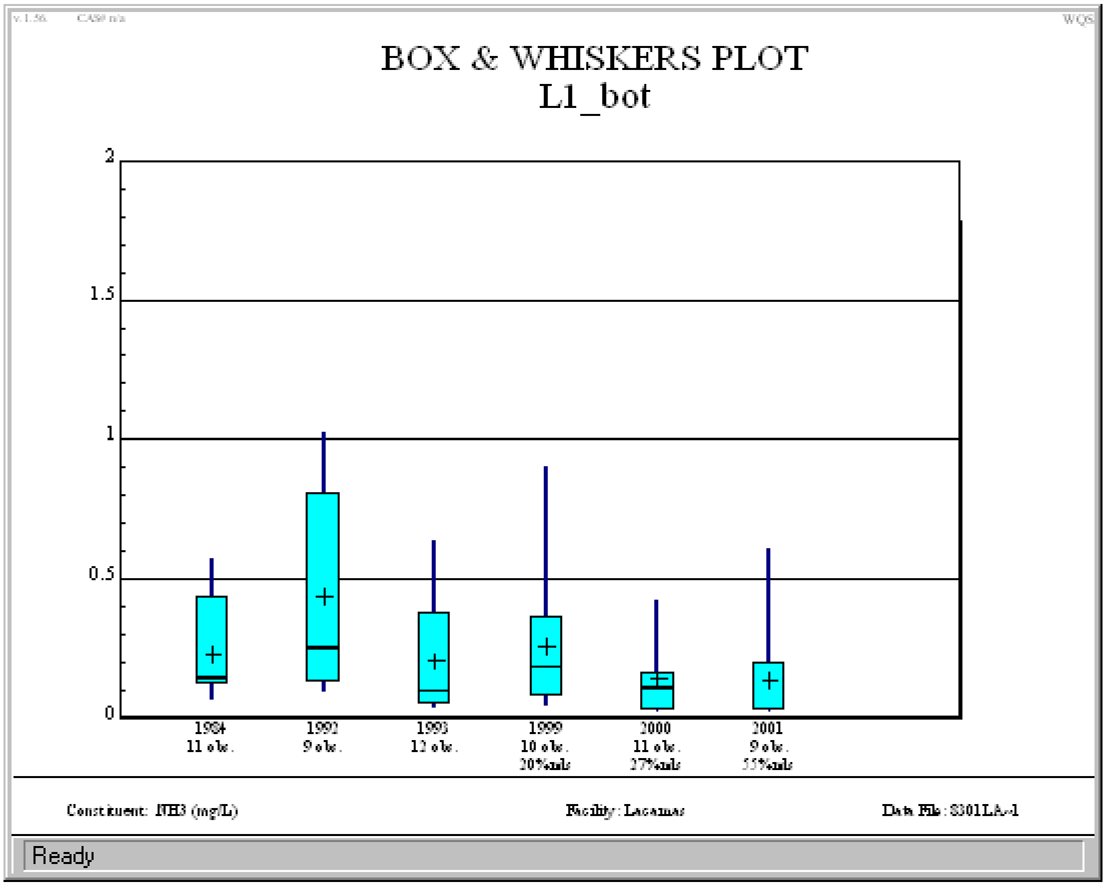
Appendix 8: Annual Box-and-Whisker plots, Lacamas Lake hypolimnion, 1983-2001



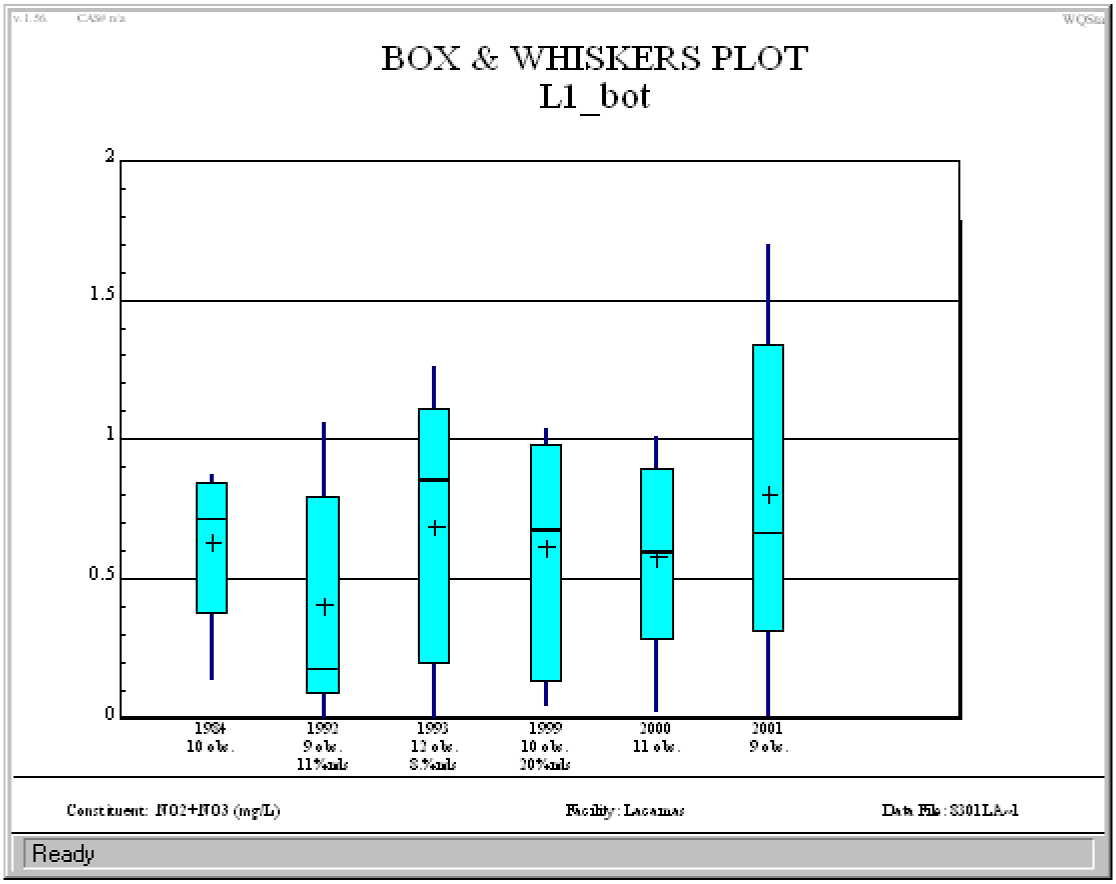


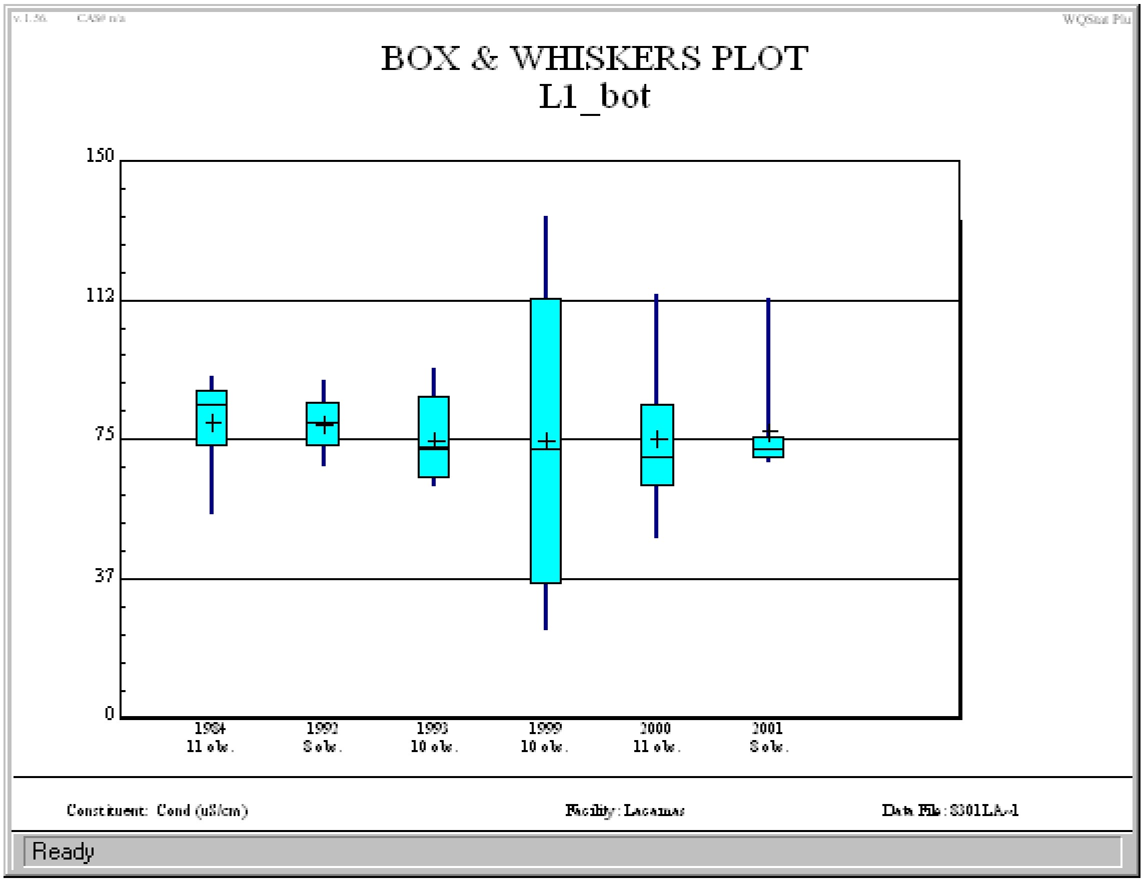
v.1.56.
CAS# n/a
WQ
BOX & WHISKERS PLOT
L1_bot
0.4
0.3
0.2
0.1
0
1984
11 obs.
1992
8 obs.
1993
12 obs.
1999
10 obs.
2000
11 obs.
18%nds
2001
9 obs.
Constituent: OP (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready


BOX & WHISKERS PLOT
L1_bot
2
1.5
1
0.5
0
1984
11 obs.
1992
9 obs.
1993
12 obs.
1999
10 obs.
80%nds
2000
11 obs.
18%nds
2001
9 obs.
22%nds
Constituent: TKN (mg/L)
Facility: Lacamas
Data File: S301LA~1
Ready



BOX & WHISKERS PLOT
L1_bot
2
1.5
1
0.5
0
1984
11 obs.
1992
9 obs.
1993
12 obs.
1999
10 obs.
20%nds
2000
11 obs.
27%nds
2001
9 obs.
55%nds
Constituent: NH3 (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready


BOX & WHISKERS PLOT
L1_bot
2
1.5
1
0.5
0
1984
10 obs.
1992
9 obs.
11%nds
1993
12 obs.
8.%nds
1999
10 obs.
20%nds
2000
11 obs.
2001
9 obs.
Constituent: NO2+NO3 (mg/L)
Facility: Lacamas
Data File: S301LA-1
Ready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CAS# n/a
WQStat Plus
BOX & WHISKERS PLOT
L1_bot
150
112
75
37
0
1984
11 obs.
1992
8 obs.
1993
10 obs.
1999
10 obs.
2000
11 obs.
2001
8 obs.
Constituent: Cond (uS/cm)
Facility: Lacamas
Data File: S301LA-1
Ready

Appendix 9: 2001 Matney Creek and Dwyer Creek Subwatershed Survey: Habitat and Benthic Macroinvertebrates

2001 Matney Creek and Dwyer Creek Subwatershed Survey: Habitat and Benthic Macroinvertebrates

Clark County Public Works
Water Resources Section

Prepared for:

State of Washington Department of Ecology
Lacamas Lake Restoration Program Advisory Committee
Clark County Clean Water Commission

Prepared by

Jeff Schnabel

March 2002

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Acknowledgements

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Special thanks to the participating landowners. Your cooperation made this project possible, and your support is greatly appreciated.

1.0 Introduction

1.1 Purpose

This report briefly summarizes the planning, field activities, and results of a prototype survey of habitat and biological health at seven sites in the Matney Creek and Dwyer Creek subwatersheds in Clark County.

This project was co-sponsored by Clark County's Lacamas Lake Restoration Program (LLRP) and NPDES Clean Water Program (CWP).

The project was designed with several purposes in mind, including:

1) Determine the feasibility of accessing private lands for monitoring projects.

2) Enhance existing knowledge about the Matney Creek and Dwyer Creek subwatersheds for use in developing an interim Lacamas Creek watershed plan.

3) Test a prototype for conducting subwatershed-scale stream habitat and biological health surveys in Clark County watersheds.

2.0 Methods

2.1 Site selection process

The project objective was to evaluate approximately 10 locations within three sub-watersheds of the Lacamas Creek watershed. Matney Creek, Dwyer Creek, and China Ditch sub-watersheds were selected as representative of a variety of land-use types within the watershed (See Figures 2 and 3): Matney Creek contains areas of agriculture, forest, and large-lot residential development. Dwyer Creek has experienced significant land-use conversion from agriculture to urban residential and commercial development. China Ditch remains largely agricultural, with areas of residential development. As part of a separate project, data were collected from a high quality site on Jones Creek, in the nearby Washougal River watershed. These data were used for comparison purposes.

Standard monitoring protocols for habitat and benthic macroinvertebrates require access to stream reaches at least 400 feet long. Therefore, in most locations it was necessary to obtain permission to enter private property.

Potential monitoring sites were identified using the county's Geographic Information System (GIS). First, all public road crossings over each creek were located on a computer-generated map. Starting from each road crossing, 500-foot stream reaches were delineated both upstream and downstream. A list was compiled of all landowners with property bordering the creek within the 500-foot stream reaches.

An inquiry letter was sent to each landowner, requesting permission to access the property during the survey. A total of 79 letters were mailed. Copies of the inquiry letter are on file with Clark County.

Responses to the letter were recorded and mapped. A set of seven monitoring sites was selected from the locations where access was granted, with the secondary goal of distributing monitoring sites evenly throughout the subwatersheds.

Figure 1 depicts the location of the Matney Creek and Dwyer Creek subwatersheds within the Lacamas Creek watershed. Figure 2 and Figure 3 show the locations of the Matney and Dwyer subwatershed monitoring sites, respectively.

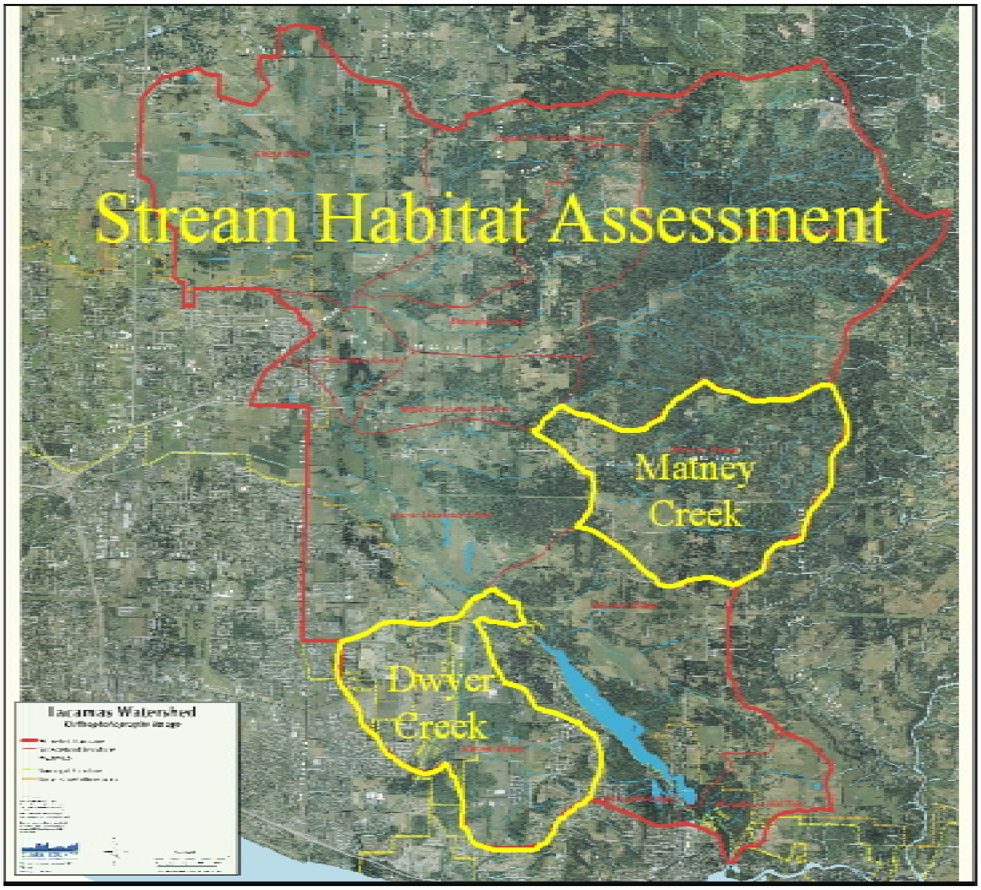

Figure 1. Location of the Dwyer Creek and Matney Creek subwatersheds within the Lacamas Creek watershed.

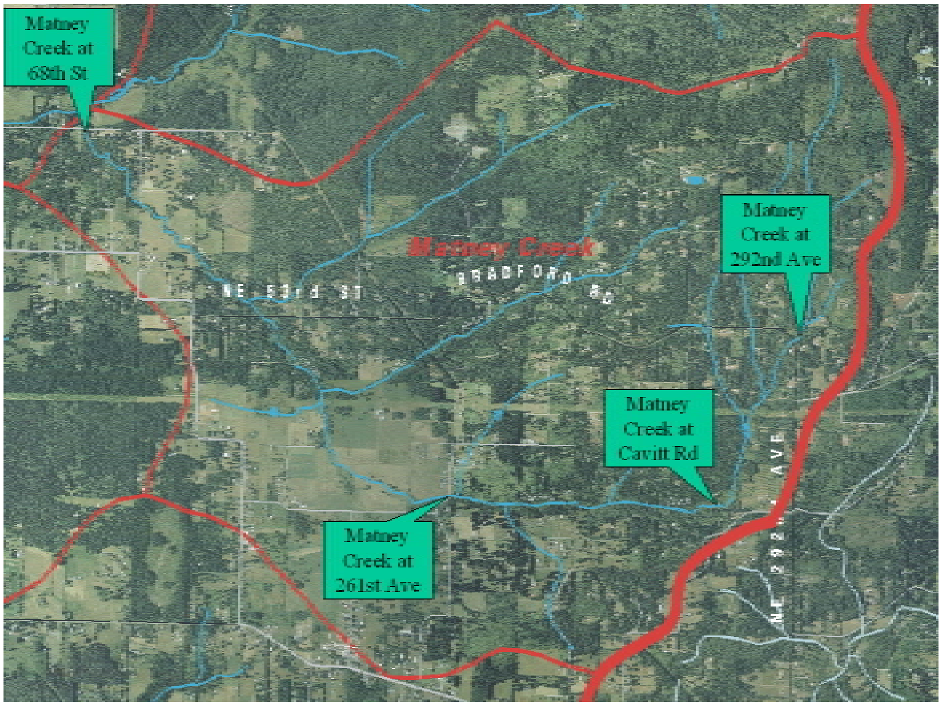

Figure 2. Matney Creek habitat and benthic macroinvertebrate monitoring sites, 2001.

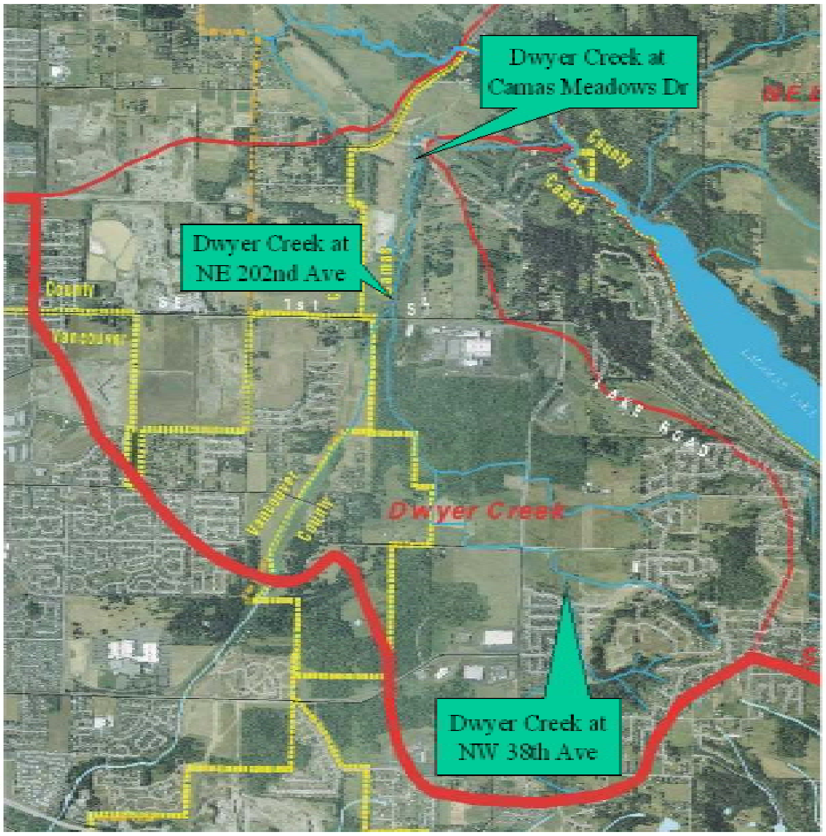

Figure 3. Dwyer Creek habitat and benthic macroinvertebrate monitoring sites, 2001.

2.2 Field methods

Monitoring was performed at the Matney Creek sites on September 19-21, 2001, and the Dwyer Creek sites on September 24, 2001.

2.2.1 Habitat

Habitat monitoring was performed according to a modified version of the U.S. Environmental Protection Agency (EPA) Rapid Habitat Assessment protocol (1999).

Each stream was visually evaluated for a distance of approximately 40 times the average stream width. In most cases, this amounted to a 400-800 foot stream reach. Ten habitat parameters were scored from 0-20 points each, for a total possible score of 200. Due to the subjective nature of visual surveys, all surveys were conducted by a team of three trained staff members. Differences in opinion were discussed on-site until consensus was reached. Final scores fall into one of four habitat quality categories: Poor (0-50), Marginal (50-100), Sub-optimal (100-150), and Optimal (150-200).

A slightly different set of parameters is used for low gradient (<5% slope) and high gradient (>5% slope) streams because optimal habitat conditions differ depending on the slope of the stream channel. The parameters for high and low gradient streams and a brief description of each are included in Table 1.

2.2.2 Benthic Macroinvertebrates (Bugs)

Benthic macroinvertebrate samples were collected according to the State of Washington Department of Ecology (Ecology) protocol (Plotnikoff, 2001). Four riffles were selected at each site. A D-frame net was placed in the stream perpendicular to the stream flow, and a 2-ft^2 area upstream of the net was disturbed. Rocks larger than 2" in diameter were scrubbed by hand, and the substrate was disturbed to a depth of 4". Organisms were placed in the net or swept into the net by the streamflow. The four riffle samples were composited into a single sample representing the entire site.

Composite samples were stored in 1-L Nalgene bottles. Macroinvertebrate samples were preserved with 95% ethanol and placed in coolers for delivery to the office. Samples were refrigerated until delivery to the lab for analysis.

2.3 Laboratory Methods

Laboratory analysis of the bug samples was performed by Aquatic Biology Associates, Inc. (ABA) in Corvallis, Oregon. Samples were processed and analyzed according to standard Ecology protocols (Plotnikoff, 2001). A minimum of 500 organisms are identified from each sample, usually down to the species level. Results are categorized into various "metrics" based on species, feeding method, sensitivity to pollution, and other factors.

Several standard population metrics are combined to form an aggregate score called the Benthic Index of Biological Integrity (B-IBI) (Karr, 1987). This score may range from 10 to 50, and the results are grouped into three categories of biological integrity or health: Low integrity (10-24), Moderate integrity (25-39), and High integrity (>40). High integrity indicates that the stream is healthy and capable of supporting optimal levels of aquatic life.

Low Gradient Streams (<5% slope)

Habitat Parameter	General question
Epifaunal substrate	Are there rocks, snags, etc that provide cover for fish and bugs
Pool substrate	What kind of material is at the bottom of the pools
Pool variability	Is there a good mix of large, deep, small, and shallow pools
Sediment deposition	Is there excessive sediment deposition
Channel flow status	Does the channel have water from bank to bank
Channel alteration	Has the channel been constricted by man-made means
Channel sinuosity	Does the stream meander naturally
Bank stability	Is there significant bank erosion
Bank vegetative cover	Is the riparian vegetation thick and is it native
Riparian vegetation width	How wide is the riparian forest zone

High Gradient Streams (>5% slope)

Habitat Parameter	General question
Epifaunal substrate	Are there rocks, snags, etc that provide cover for fish and bugs
Embeddedness	How much fine sediment is packed around the gravel
Velocity/Depth Regime	Is there a good mix of fast, slow, shallow, and deep areas
Sediment movement	Is there significant transport of material into or out of the reach
Channel flow status	Does the channel have water from bank to bank
Channel alteration	Has the channel been constricted by man-made means
Frequency of riffles	How much riffle habitat is present
Bank stability	Is there significant bank erosion
Bank vegetative cover	Is the riparian vegetation thick and is it native
Riparian vegetation width	How wide is the riparian forest zone

Table 1: Habitat parameters evaluated in the EPA Rapid Habitat Assessment protocol (simplified from field form).

3.0 Results

3.1 Access

Landowner response to the letter of inquiry was very positive. Out of 79 letters mailed, 47 responses were received (a return rate of 59%). Forty-one of the 47 responders granted permission to access their property (87%).

Though many positive responses were received from private landowners in the China Ditch subwatershed, the commissioners of the China Ditch Drainage Improvement District (DID #5) asked that the county not collect data from within their system. DID #5 is responsible for maintaining the laterals and ditches of the China Ditch drainage system. The China Ditch subwatershed was therefore eliminated from the project scope.

3.2 Habitat

Figure 4 shows the overall results of the Rapid Habitat Assessment in Matney and Dwyer Creeks, respectively. A high-quality site at Jones Creek (in the Washougal River watershed) is included for comparison.

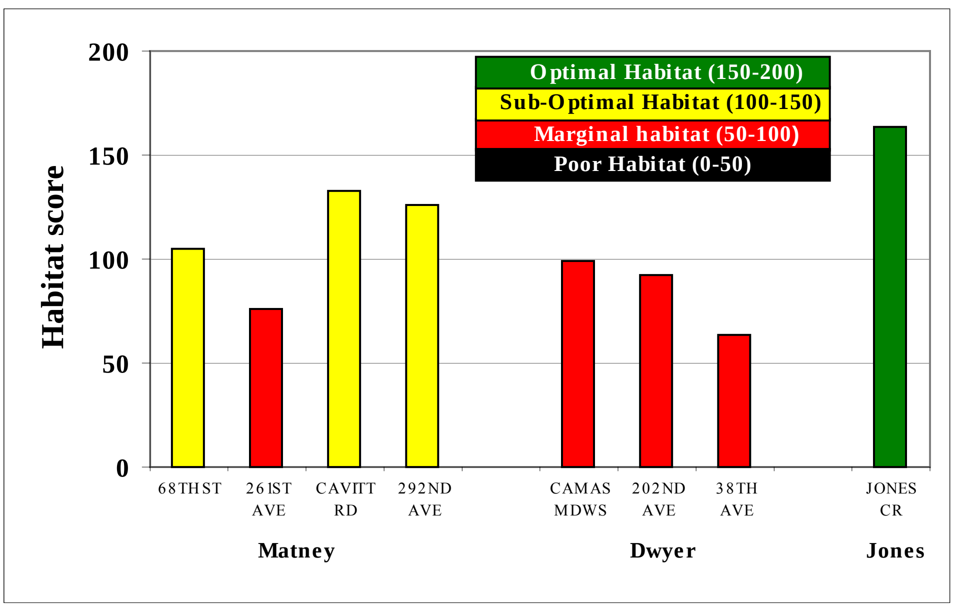

Figure 4. Matney Creek and Dwyer Creek EPA Rapid Habitat Assessment scores, 2001. Jones Creek site included for comparison.

A maximum score of 200 is possible. Scores in the Matney subwatershed ranged from 76 at the NE 261st Street site to 133 at the Cavitt Road site, with the 292nd Avenue and 68th Street sites at 126 and 105, respectively. In Dwyer Creek, scores ranged from 63 at NW 38th Avenue to 99 at Camas Meadows Drive, while the site at NE 202nd Avenue scored 92. The Jones Creek comparison site scored 163.

3.3 Benthic Macroinvertebrates

A maximum B-IBI score of 50 is possible. B-IBI scores for the Matney Creek and Dwyer Creek sites are shown in Figure 5. A high quality site at Jones Creek (in the Washougal River watershed) is included for comparison.

Scores in the Matney Creek subwatershed ranged from 22 at the Cavitt Road site to 42 at NE 292nd Avenue, while the 68th Street and 261st Avenue sites scored 34 and 24, respectively. In Dwyer Creek, the Camas Meadows Road site scored 22 and NE 202nd Avenue scored 26. No benthic invertebrate sample was collected at the NW 38th Avenue site because it was lacking suitable riffle habitat. The Jones Creek comparison site scored 46.

3.4 Habitat and Bugs vs Road Density

Road density (miles of road/mile^2) or other land-use factors are sometimes used to estimate the amount of human impact on watersheds and predict relative stream health. In this study, road density (which includes both public and private roads and driveways) was calculated for the areas draining to each of the monitoring sites. Habitat scores and bug scores were plotted against the road density to determine whether a relationship exists between these factors.

Although there are few data points, we can begin to see possible patterns. In general, as the road density increases, both habitat quality and biological integrity tend to decrease. As more sites are analyzed in the County, the statistical relationships between various factors should become stronger. Figure 6 and Figure 7 are included as preliminary examples of these possible relationships.

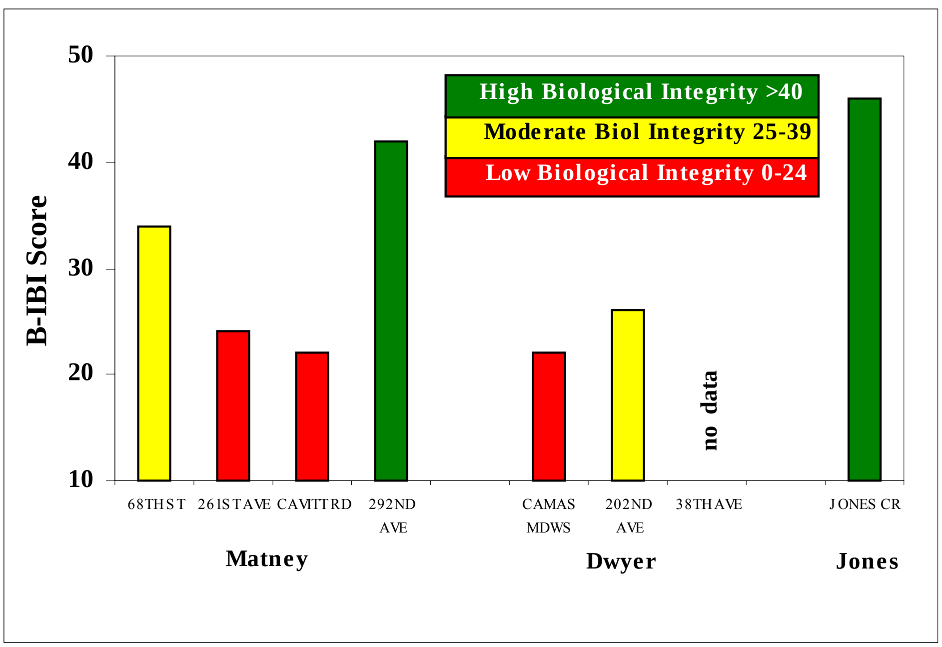

Figure 5. Matney Creek and Dwyer Creek B-IBI scores, August 2001. Jones Creek included for comparison.

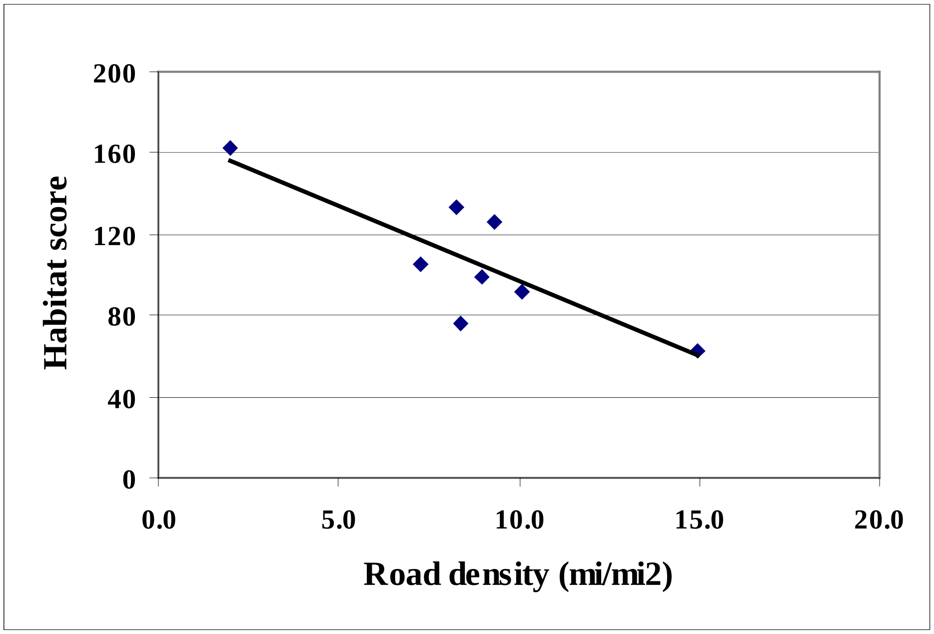

Figure 6. Habitat score vs. road density, Matney and Dwyer Creek sites, 2001. Also includes Jones Creek comparison site.

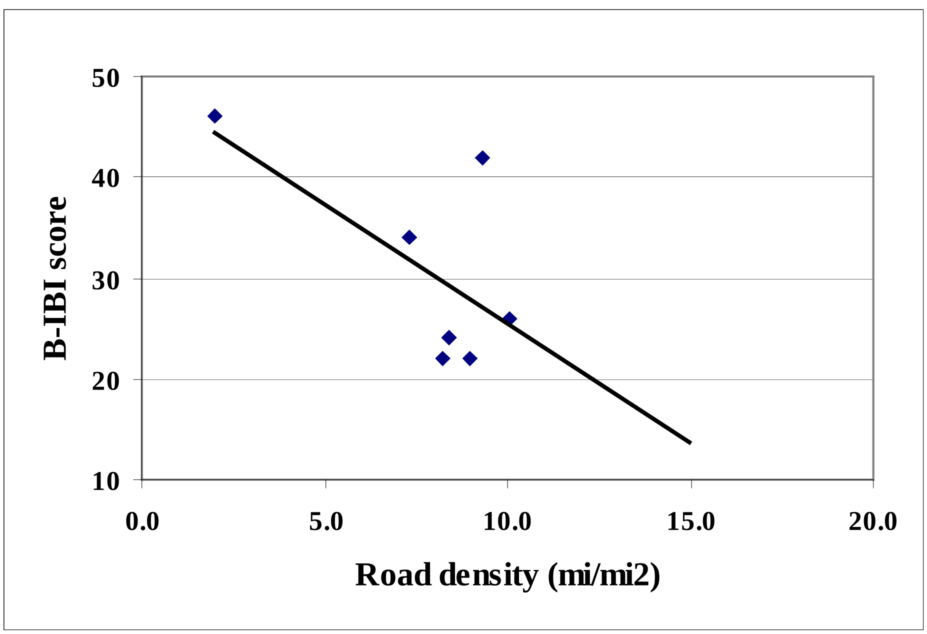

Figure 7. Bug (B-IBI) score vs. road density, Matney and Dwyer Creek sites, 2001. Also includes Jones Creek comparison site.

4.0 Discussion

4.1 Feasibility of Accessing Private Lands

Based on the response to this survey request, it appears that accessing private lands for one-time stream studies is a viable approach. The positive response rate was 52%. This was considerably higher than anticipated. In fact, so many sites were made available that we were unable to include all of them under the scope of this project. Even if positive responses in other areas of Clark County are significantly lower, it appears that sufficient sites should be available for similar projects.

An important secondary benefit of this approach was also evident. Communication with streamside landowners during this project resulted in several opportunities for staff to address public inquiries and provide additional information. In some cases, interested landowners were put in contact with other organizations, such as the Clark Conservation District and the Columbia Land Trust, for assistance in enhancing and managing their property.

4.2 Enhance Existing Knowledge about Matney and Dwyer Creeks

The second purpose of this project was to enhance existing knowledge about the Matney Creek and Dwyer Creek subwatersheds for Lacamas Creek watershed planning. The watershed analysis and plan were developed through Clark County's grant-funded Lacamas Lake Restoration Program. The Lacamas grant program concluded in December 2001. The following is a general discussion of conditions at the monitored sites:

Overall, habitat quality and biological integrity varied with the degree of human disturbance in the subwatersheds.

Jones Creek Reference Site: Reference sites are areas which can be compared to other sites with similar natural characteristics in order to gauge the impact from human activities. If a reference site begins to show signs of degradation, it may mean that climatic or natural hydrologic factors are influencing all of the streams in the surrounding area. Conversely, if the reference site remains healthy while similar sites nearby begin to degrade, it may mean that human activities are having a negative impact on stream health.

The Jones Creek site is located on land owned by the City of Camas, upstream from the City's public water supply intake. The area is closed to public entry and has very few roads. Although the area has been logged historically, the entire watershed above the sampling site is currently forested. The fact that this area is minimally impacted by human activities makes it a good reference or comparison site candidate.

In 2001, the Jones Creek site scored in the highest category for both biological integrity and habitat condition. It also has the lowest road density of any of the monitoring sites at approximately 2 miles of road per square mile.

Matney Creek: Results for the Matney Creek subwatershed are generally consistent with what might be expected in a developing rural area. Land use patterns are altered from their pre-development forested condition. The highest occurrence of residential development and agricultural clearing is in the middle of the subwatershed. Throughout the subwatershed, road densities are considerably higher than in Jones Creek, ranging from approximately 7-9 miles of road per square mile.

Habitat and benthic invertebrate scores were lower than the Jones Creek scores at all monitored sites, but some sites still exhibit good habitat characteristics and moderate to high B-IBI scores.

The 261st Ave site was the only site exhibiting both low biological integrity and marginal habitat quality. This area is the most intensively cleared site, and has been subjected to historical modifications such as channel straightening and wetland draining to a greater extent than the other sites.

The Cavitt Road site is the only site where habitat and benthic invertebrate scores did not match well with each other. This site was characterized by a series of natural beaver ponds and wetlands. These characteristics resulted in generally good habitat scores, but the slower moving, ponded water is not prime benthic invertebrate habitat and resulted in a low score for biological integrity. Despite the low B-IBI score, this area represents an important piece of intact wetland, serving to control runoff, provide wildlife habitat, and facilitate groundwater recharge.

Based on the overall habitat and B-IBI scores, the Matney subwatershed has reduced biological integrity and habitat quality due to human activity (compared to a forested condition). However, many parts of the stream system remain healthy or are only moderately impaired.

Dwyer Creek: Land cover in the Dwyer Creek subwatershed has been significantly altered from its historical condition. In this rapidly developing area, nearly all of the native forest has been cleared to make room for agriculture, residential and commercial development, gravel mining, and golf courses. Road densities in Dwyer Creek range from 9-15 miles of road per square mile, with the highest densities occurring in the headwater region.

Habitat and biological integrity scores in Dwyer Creek were consistently much lower than the Jones Creek site, and generally lower than the Matney Creek sites. All three monitoring sites in Dwyer Creek exhibited only marginal habitat, and the two sites with B-IBI scores ranked in the low and moderate categories for biological integrity. The 38th Ave site was not sampled for benthic invertebrates because not enough suitable habitat could be found to collect a proper sample. In this situation, it is very likely that the biological integrity of the site is quite low.

Based on overall scores, the habitat and biological integrity of the Dwyer Creek subwatershed is significantly degraded by human activities. Few areas of native forest remain intact, and the biological and habitat conditions are uniformly degraded throughout much of the area when compared to the likely historical condition represented by Jones Creek.

4.3 Test a prototype for conducting future habitat and biological health surveys

The final purpose of this prototype study was to determine whether this approach would be useful in future planning and monitoring efforts. To that end, this project utilized protocols already in use by the county and other jurisdictions to collect comparable data. As a result, data collected for this project can be easily combined with data from other county or outside agency projects to form larger, comprehensive data sets. Some of this compilation has already occurred, allowing the county to utilize these data for multiple purposes.

The apparent openness of private landowners to allow access to streams, coupled with the public outreach benefits, also encourages the use of this format in other areas.

Field work for this project was completed at the rate of 2-3 sites per day. At this rate, a large number of sites can be surveyed in a short time-frame, which is often critical when collecting characterization data for basin planning efforts.

Based on this initial trial, the study format appears to offer a straightforward and reproducible means to collect basic watershed characterization information in a timely manner. Two possible modifications to the protocol are:

1) Revise criteria separating low and high gradient streams. Since a 5% gradient is quite steep, most streams tend to be grouped in the “low gradient” category. Using a 3% gradient as the distinction between low and high gradient streams would ensure that streams in each category exhibit more similar morphological and flow conditions.

2) Add a requirement to document the reason for any habitat score that was not unanimously agreed upon. This would add an additional level of quality control and consistency among measurements.

With minor modifications such as these, and somewhat more in depth data analysis, this prototype should lend itself to short-term, intensive monitoring projects related to Clark County’s capital improvement planning, watershed characterization, and basin planning efforts.

References

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Plotnikoff, R. (June 2001). *Benthic Macroinvertebrate Biological Monitoring Protocols for Rivers and Streams.* 2001 revision. Washington Department of Ecology.

US EPA, (July 1999). *Rapid Assessment Protocols for Use in Wadeable Streams and Rivers – Periphyton, Benthic Macroinvertebrates, and Fish*. Office of Water, Publication EPA 841-B-99-002.